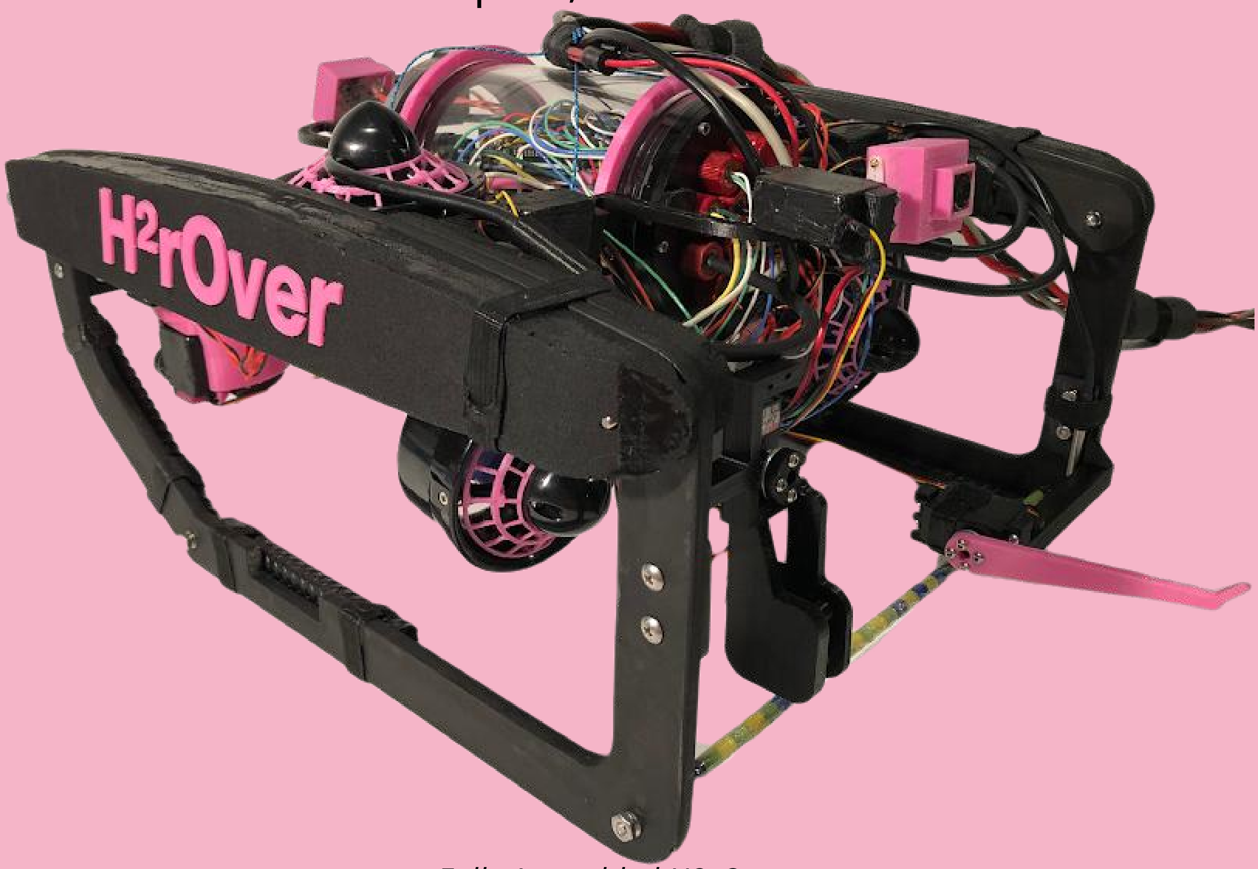
Curiodyssea

MATE ROV International Competition

Staples High School

Westport, Connecticut



Fully Assembled H2rOver

Company Staff

Nicholas Durkin (12th)

Chief Executive Officer, Control and Electrical Engineer, Data Analyst

Tyler Edwards (11th)

Chief Information Officer, Software and Mission Engineer, Mission Strategist

John McNab (12th)

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

Nathan Wang (11th)

Chief Safety Officer, Visual Systems Engineer, Tether Manager

Daniel Westphal (12th)

Chief Marketing Officer, Propulsion Systems Engineer, Pilot

Mentors: Mike Durkin and Andy McNab

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Abstract

Curiodyssea constructed the H2rOver – Project Mantis Shrimp, its fourth generation remotely operated vehicle (ROV), to meet the RFP requirements put forth by Eastman, a global specialty chemical company. The H2rOver is designed to be a versatile vehicle which can maneuver through Boone Lake, Boone Dam, and the South Fork of the Holston River all while protecting and ensuring the well-being of the marine environment.

The H2rOver is able to inspect and repair a hydroelectric dam, monitor water quality, determine habitat diversity, and recover and preserve historical artifacts. H2rOver features a state of the art chassis and propulsion system, onshore guidance and control system, integrated multi-camera video system, and custom designed mission tools.

The H2rOver is equipped with four motors (including two custom gimbal mounts developed by Curiodyssea), four cameras, and specialized mission attachments. The chassis of the H2rOver is made from composite G-10 epoxy laminate and ultra high density foam, which are sturdy, light, and can be cut with a computerized water jet. The control system of H2rOver is comprised of an onboard Arduino, custom control software developed in Processing (Java language), and a Logitech F310 gamepad.

Curiodyssea is a company committed to manufacturing cost-effective, compact, and efficient ROVs that are capable of operating in any type of marine environment and performing mission critical tasks for years to come.

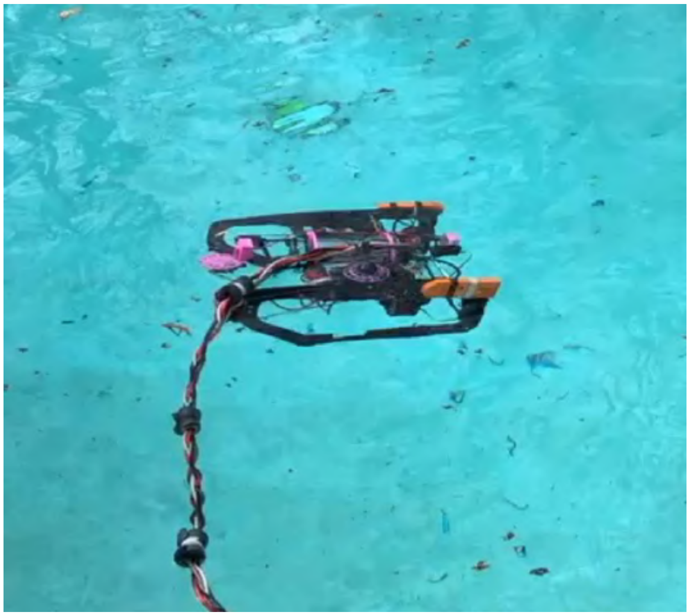


Figure 1: An early underwater test of the H2rOver

Technical and Scientific Concepts Behind the ROV

After receiving the 2019 Eastman RFP, Curiodyssea assessed the components and systems necessary to build an ROV that could complete the RFP specified underwater missions. Based on this assessment, a company objective for the ROV was established: build a remotely operated vehicle which uses multiple subsystems (cameras, attachments, etc.) to effectively and affordably accomplish underwater missions while adhering to the size and weight restrictions for the requested ROV. Subsequently, Curiodyssea did a thorough review of the *Underwater Robotics* textbook, and several key ROV concepts were identified and evaluated: structure and materials, buoyancy and stability, movement, power systems, navigation and control, and payloads.

The Curiodyssea production team is organized based on systems and expertise; each team member is assigned lead responsibility for one of the ROV's core systems based on their expertise. Nicholas Durkin - electronics and control; Tyler Edwards - software and mission design; John McNab - chassis design; Nathan Wang - camera systems; Daniel Westphal - propulsion. The team worked together to design and build the specific mission systems.

After reviewing the RFP, the team created a list of the required parts/systems, and a model was designed in Solidworks (3D design software) to see how all the parts would connect. Prototypes of the ROV and attachments were virtually tested in Solidworks to identify possible issues and spatial requirements. This virtual testing of ROV concepts and systems saved time, money, and resources.

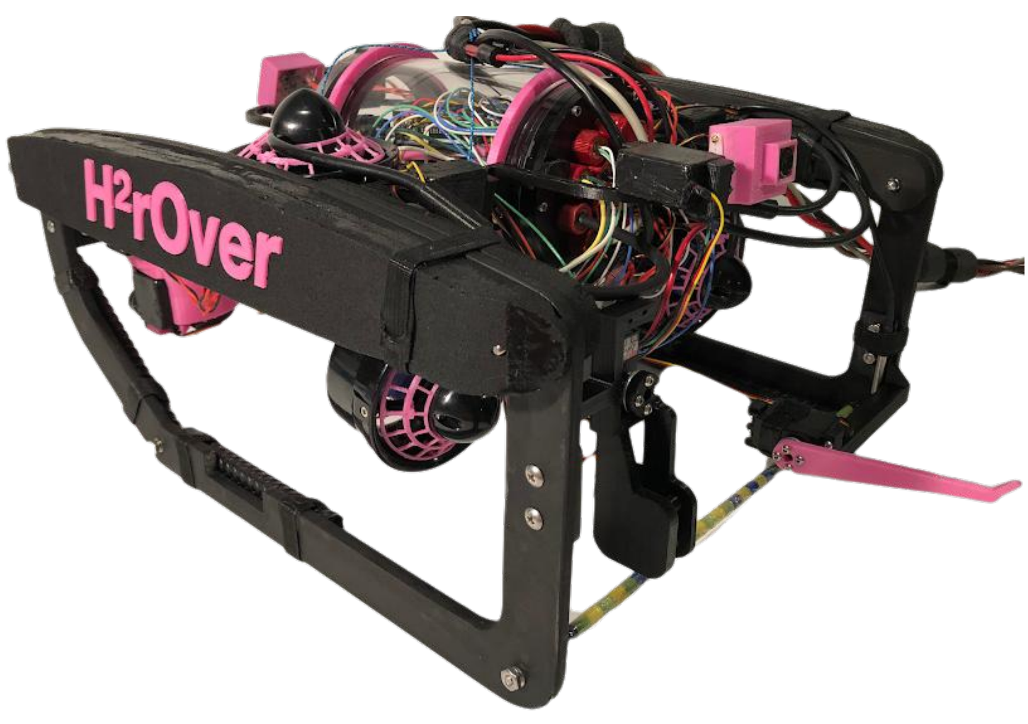


Figure 2: Fully assembled H2rOver - Project Mantis Shrimp

Budget Planning

After three years of experience in the MATE competition, Curiodyssea has a good understanding of how much it costs to create a reliable ROV and travel to the competitions. Curiodyssea estimated that the ROV would cost $565, as many components and materials could be reused from previous years. In order to achieve this budget, Curiodyssea asked each of its five team members to donate $115 for the ROV.

Budget		
Section	**Cost**	**Components**
Tether	$20.00	New Cat 6 cable, reused RS232 and power cables
Chassis	$250.00	G10, foam, machining, screws
Motors	$35.00	Reused T100s, PLA plastic, servos
Electronics	$20.00	Reused controllers and wiring, new sensor
Cameras	$70.00	Baluns, cameras, monitors, mixer
Attachments	$100.00	PLA plastic, servos
MicROV	$60.00	Motor, extending links, camera
Lift Bag System	$10.00	Reused Lift Bag, PLA plastic, pump
ROV Total	**$565.00**	
Registration	$150	Fee
Travel	$5,000	Travel, Lodging, Food
Subtotal	$5,150	
Total	$5,715.00	

Project Costing

By securing contributions, reusing old parts and carefully managing expenditures, Curiodyssea built the fourth iteration of H2rOver under budget. The final ROV cost was $498 in new expenditures, which was $67 less than expected.

Project Costing

Reused Items		
Description	Year	Value
T100s and ESC's	2018	$600.00
Cameras	2016	$15.00
Camera Mixer	2016	$115.00
T-Shirts	2016	$150.00
Arduino Mega	2016	$28.49
Game Controller	2016	$27.29
Fuse Holders	2016	$16.99
Tools and Supplies	2016	$231.13
Computer Monitor	2017	$100.00
Watertight Case	2018	$249.00
Tether Components	2018	$40.00
Control Box	2018	$60.00
Lift Bag	2018	$63.20
Total		$1,183.90

Donated		
Description	Source	Value
Waterjet Cutting	Steinmetz Machine Works	$105.00
Total		$105.00

New Expenditures	
Description	Cost
Servos	$34.47
Ethernet Cable	$64.92
Temperature Sensor	$10.00
PLA plastic	$35.00
Materials (Epoxy)	$70.57
Screws and other Misc	$40.25
Servos	$90.00
Cameras	$47.00
LED Light	$11.89
G10	$93.47
ROV Total	**$497.57**

Travel and Other Expenditures	
Description	Cost
Transportation	$1,500.00
Food	$1,000.00
Registration	$100.00
Lodging	$2,000.00
Total	$4,600.00

Project Total	$5,097.57

Design Rationale

Curiodyssea's design rationale follows a system-based methodology which divides the ROV into systems (electronics, chassis, vision, propulsion, attachments), and then divides those systems into components. Each component is designed, tested (in the workshop and in water), and integrated into the respective system. Then each complete system is tested independently, before incorporating it into the final ROV. This enables Curiodyssea to have confidence in the operation of all systems before assembly.

Following the lessons learned from Curiodyssea's previous ROVs, the H2rOver is developed with a modular design focus. This allows the H2rOver to be easily taken apart and reconstructed, allowing the company to update/repair certain components, isolate individual systems, as well as easily and safely transport the ROV.

Curiodyssea focused on improving the speed and maneuverability of its H2rOver this year. This improvement was achieved by minimizing weight and utilizing stronger thrusters. These upgrades make the H2rOver a highly functional ROV, capable of both quick and precise movement, enabling the H2rOver to accomplish a wide range of tasks.

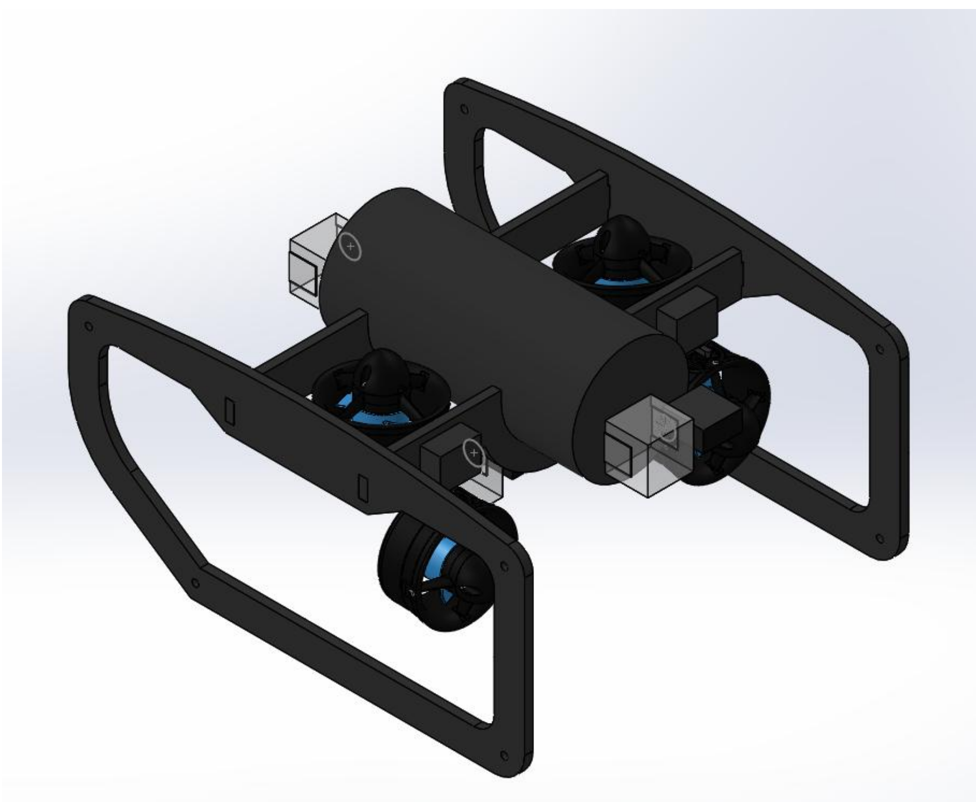


Figure 3: Solidworks mechanical model of H2rOver

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

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

Availability - Specific or customized attachments are often unavailable for purchase. Depending upon the component, the product may only be available overseas, which is difficult when you need replacement parts.

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

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.

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

Chassis

The chassis was designed in Solidworks, a 3D design program used by engineers worldwide. Designing the chassis using this software allowed us to test different ROV designs and components without having to build physical models. Once the chassis design was finalized, the design files were exported to a professional machine shop and precision cut by water jet.

Figure 4: Completed laminate chassis frame

The design focus when creating the chassis was to keep it lightweight but structurally sound. In order to achieve this, Curiodyssea selected an open design which consists of two vertical plates connected by two cross-bars. This design allows for perfect lines of sight from the cameras, as well as open mounting space for numerous attachments.

To minimize weight, the chassis was created out of a composite of G-10 epoxy laminate and ultra high density foam. This composite was created by layering two sheets of G-10 around two sheets of foam, epoxying them together, then vacuum bagging them to ensure the epoxy spread evenly. These sheets are incredibly strong, lightweight, and positively buoyant, so less buoyancy must be added.

Figure 5: G-10 Laminate chassis frame being vacuum bagged

The modular chassis has four distinct structural components and can easily be reassembled using a system of bolts and interlocking parts (components slide into designated slots). This allows for quick breakdown of the ROV for updates, repairs, and easy shipping.

Buoyancy and Stability

A neutrally buoyant, stable ROV is essential to complete missions, avoid drift when working on mission tasks, and have consistent navigational movement. To optimize the buoyancy and stability of H2rOver, the center of mass was lowered by putting rebar weights on the bottom of the chassis and the center of buoyancy was raised by adding flotation on the chassis' top. There are many factors that influence the overall buoyancy of the ROV, but the most significant ones are the buoyant foam, the positively buoyant chassis material, the watertight case, and the ballasts. Curiodyssea installed high density foam along the upper edges of the ROV in order to move the center of buoyancy upwards over the center of mass. Keeping these two points in line maximizes the overall stability. The bottoms of the chassis act as skids which allow rebar to be easily installed to increase ballast at the lowest points of the ROV. By optimizing the positions of the center of buoyancy and the center of mass, the H2rOver is a very stable, neutrally buoyant ROV.

Figure 6: Buoyant high density foam attached to the H2rOver

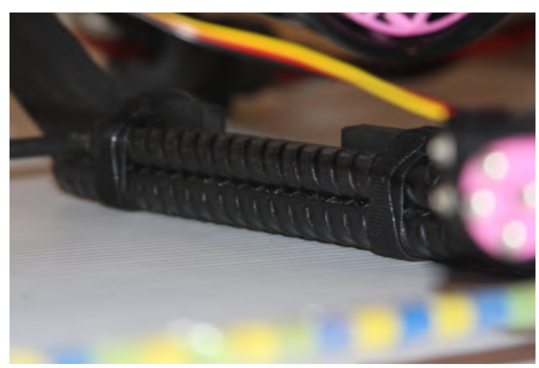


Figure 7: Rebar attached to the skids of the chassis

Propulsion

The H2rOver utilizes two vertical thrusters and two horizontal thrusters. The horizontal thrusters are mounted using Curiodyssea's custom gimbal mounts. The mounts are connected to servo motors to enable full thrust in any horizontal direction, and the vertical thrusters are fixed on 3D printed mounts. This four thruster configuration was selected over other alternatives to maximize maneuverability and speed while minimizing cost and required number of thrusters.

Figure 8: Gimbal and vertical motor mount

Curiodyssea explored several options for thrusters, including both commercial options and in-house designed custom brushless motors. Curiodyssea tested several prototype brushless thrusters utilizing a Bollard test but found that none delivered more than 3 newtons of thrust. It was determined that the time required to develop high performing brushless motors was not worth it, especially when Curiodyssea could reuse T100s from previous years and spend the time developing the full motion gimbal mounts. The power of the T100s also meant that the H2rOver only required four motors, reducing overall weight. Given all of their advantages, Curiodyssea decided that using T100s were the best option for the propulsion system.

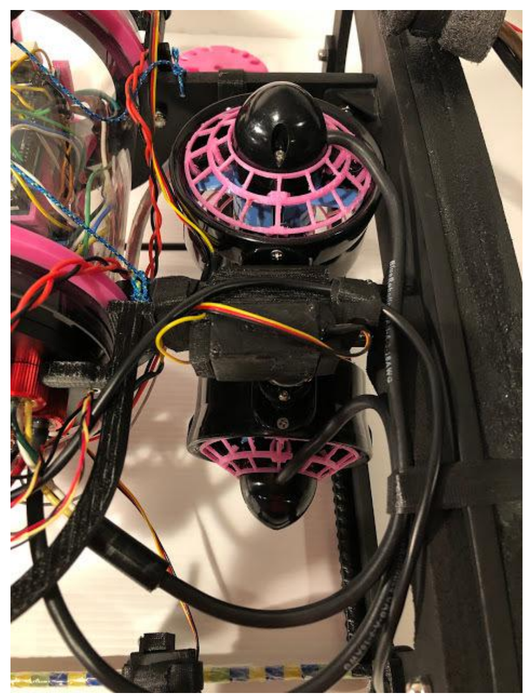


Figure 9: Motors mounted on chassis

During performance testing, the T100s produced 4.6 newtons of thrust. They can draw up to 7 amps of power, but are regulated by power management software to ensure they don't draw excess power which would shut down other electrical systems. The T100s have custom 3D printed guards to increase safety.

Camera System

Since visibility is essential to completing missions and having a functional ROV, Curiodyssea's goal was to build a multi-camera system that provides effective sightlines for all missions and general navigation. In addition, the system had to be cost-effective, lightweight, and capable of viewing and managing multiple video feeds.

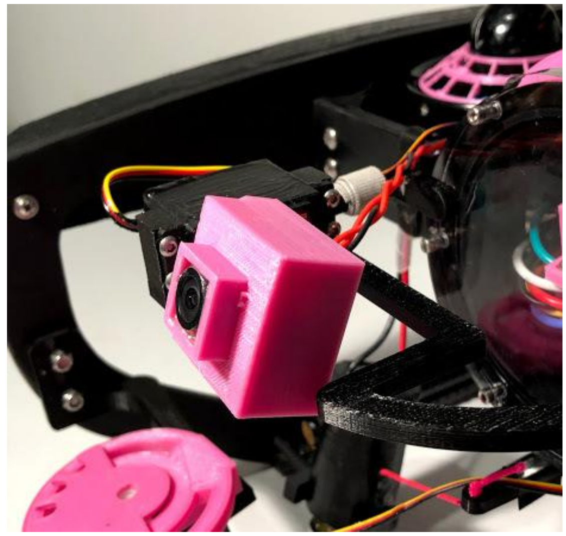


Figure 10: Back camera attached to rotating servo mount

H2rOver is equipped with three wide-angle 800TVL color board cameras that are waterproofed in custom designed 3D printed cases that minimize space and use epoxy resin as a sealant. There is one camera mounted in the front, one in the back, and one underneath the ROV to provide the vision fields necessary to complete all ROV operations. All cameras are mounted to waterproofed servos which adjust the camera view 180 degrees to dramatically increase the range of view from these camera positions.

H2rOver's video system uses a shielded Ethernet cable and two baluns to transfer video signals between the ROV and the poolside control station. One balun is situated inside the watertight case and the other is located in the topside control system. Instead of utilizing BNC (Bayonet Neill–Concelman) connectors, the three cameras are hard-wired into the onboard balun to conserve space inside the watertight case. The baluns enable the signal conversion of up to four video signals into one shielded ethernet cable which minimizes weight and makes the tether easier to manage. The shielded ethernet cable was selected to minimize electrical interference from the power cables, which can impact the quality of the video signals transferred via the tether.

To manage the multiple video feeds, the control station has a high-quality video mixer with a color quad processor that enables the simultaneous viewing of up to four cameras on one monitor without signal delay, as well as offering multiple viewing options for the pilots.

Electrical/Control System

The control system's purpose is to manage all of the electrical components on the ROV and give the pilot and co-pilot the ability to intuitively operate the vehicle. The system controls the motors and servos through an onboard Arduino Mega, which communicates with the topside controller to exchange information about motor power and sensor information. The system is designed to give easy access to components for troubleshooting or updating: all wiring connections are detachable, the watertight case is accessible, and the Arduino is easily reprogrammable.

The communication between the laptop and Arduino utilizes a packet based system to ensure all data sent and received is accurate. The communication protocol packages the signal to be sent with a corresponding hash code (a unique checksum value generated for each possible command signal). This hash code is verified at the receiving end of the signal to ensure all enclosed data is accurate.

Topside Control Station - The topside control station is composed of three main parts: the monitor (which displays the views from the ROV's cameras), the computer (running topside controls and communicating with the onboard Arduino), and the control box (which houses several control features for pilot use, including a video mixer and topside balun).

The topside control station is operated by two pilots. The main pilot operates a Logitech F310 Gamepad which steers the ROV via the four directional thrusters. The Gamepad is connected to a laptop, which runs a Processing (a Java-based program) sketch communicating with the Arduino to send motor and sensor data. The co-pilot operates an intuitive user interface which allows adjustment of the camera or attachment positions from the computer.

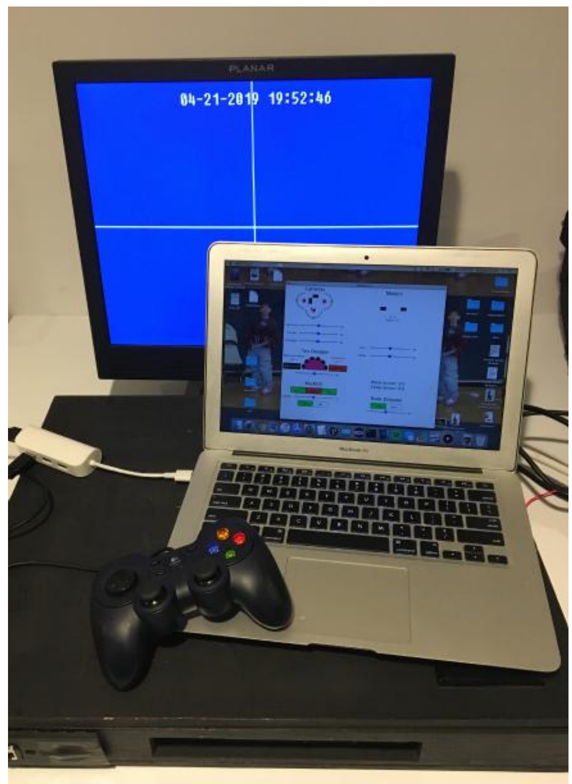


Figure 11: Topside control station including laptop running control software

Watertight Case - The watertight case contains all H2rOver's onboard electrical components. The case is designed to maximize accessibility for hardware and software changes. The components are organized on 3D printed racks and configured such that most components are removable for hardware upgrades, and for software updates, the Arduino’s USB port is located next to an end cap to enable quick access.

Figure 12: Watertight case

The case contains two signal converters, one RS232 - TLL converter, and one balun for BNC - ethernet conversion. On previous ROV designs, these components had dedicated external waterproofed boxes. By integrating these converters into the watertight case, the external wiring is simplified and these components no longer take up valuable space on the chassis.

Benthic Species Counter - The Benthic Species Counter is custom software written to identify the number of distinct, recognizable shapes in an image. It does this by first breaking down the image into discrete objects based on color. A custom neural network classifies each object as “shape” or “not shape”. The “shape” objects are then analyzed by an open source library to count contours and ultimately determine what shape the object is by the number of sides it has. The number of each shape is then summed up.

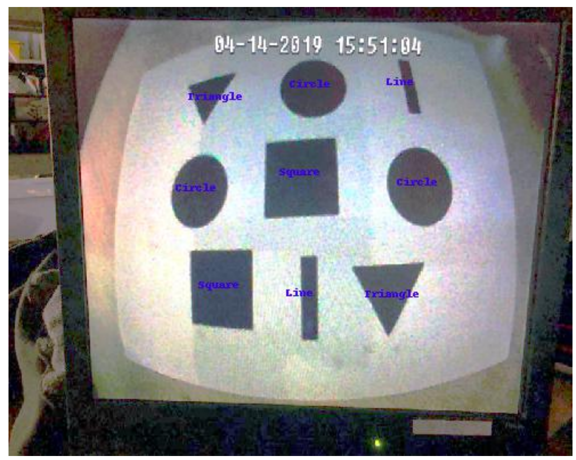


Figure 13: Image processed by the Benthic Species Counter

Tether - The tether provides all necessary connections from the topside control station to the ROV. The tether contains two 8 gauge wires for power supply, an RS232 serial cable for data communication, and a shielded ethernet cable for video signals. The tether is 15.25 meters long and allows the ROV to reach all areas of the mission field. The tether is braided to keep the wires together and wrapped with velcro ties to ensure it remains neat and manageable. The tether is secured to the ROV with a strain relief system made from four kevlar strings which center the tether on the top of the ROV. The “Mega Claw”, an expandable clip, is used to keep the tether neatly coiled during transportation and storage.

Figure 14: Braided tether coiled with Mega Claw

The tether is carefully engineered using foam rings to be neutrally buoyant, which minimizes tether drag while navigating H2rOver, making it easier to control and complete missions.

Attachments

The H2rOver has many specialized attachments to effectively manipulate and measure its environment.

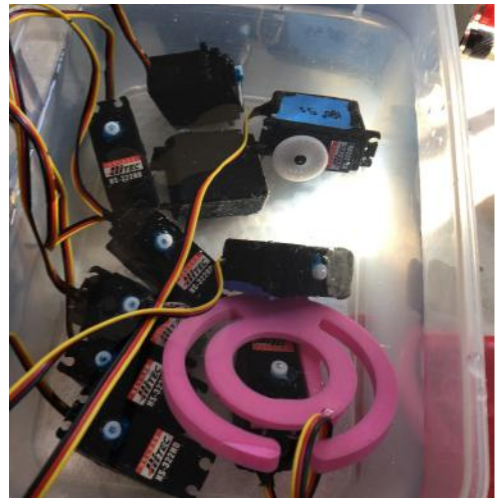


Figure 15: Servos in the process of being waterproof tested

Most of the H2rOver's attachments require movement to accomplish their tasks. Curiodyssea elected to use servo motors for these attachments because of their small footprint, high precision, and proven reliability.

The H2rOver uses 9 servos. Each servo had to be waterproofed and tested to ensure reliability. Curiodyssea waterproofs servos by spraying the circuit board with CorrosionX HD, and then filling the empty cavities with marine grease. Once waterproofed, all servos were tested for 7 hours underwater to ensure reliability before installation on the ROV.


Figure 16: Lift Bag System

Liftbag System - To assist with lifting heavier items, Curiodyssea developed a lift bag system consisting of a lift bag, two specialized connectors, and a locking mount on the H2rOver. The lift bag itself is reused from last year's challenge. The connectors and locking mounts are newly designed. The lift bag system is used for both the cannon and the tire missions since both involve heavy objects that the ROV would have difficulty moving. The specialized connectors are used to attach the liftbag to the object it needs to bring to the surface. Since the ROV does not have a traditional manipulator, a locking mount is used to clamp the lift bag onto the ROV until the lift bag is deployed. An air tube, which is used to inflate the lift bag, is directly attached to the inside of the bag, so that air pumped into it (via a bike pump) will only go into the lift bag.

Measurement Device - The H2rOver is capable of making high precision measurements using an in-house designed measurement device which is mounted on the front of the ROV. This device consists of a G-10 rod with colored markings - alternating blue and green 5 cm sections, and higher precision yellow markings every 1 cm. To measure an item the H2rOver navigates over to the targeted item, and maneuvers until the measurement device is in the proper spot. Then the bottom camera is pointed at the rod, and the measurement can easily be taken.

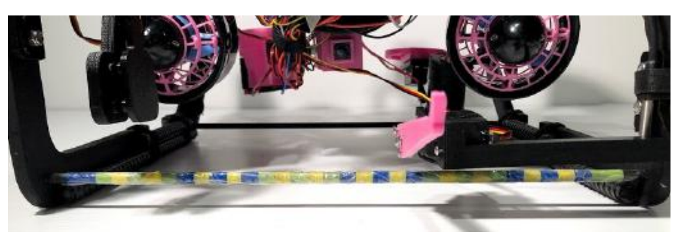


Figure 17: Measurement device

Shell Marker - The shell marker is used to transport and dispense the markers for the cannon shells. The attachment is made of 3D printed plastic and a waterproofed servo. The servo spins a servo horn with six cutouts for six markers. The slots are rotated over a cutout in the outer rim, and the selected marker drops to the cannon shell.

Figure 18: Shell Marker

Material Dispenser - The material dispenser is made of a transport cup with a hinged bottom. The dispenser serves a dual purpose. It transports both the grout and trout fry, which are loaded into the cup at the surface,and then the dispenser, using a servo to open the bottom of the cup, releases the transported materials into the designated locations for the dam or trout fry missions.

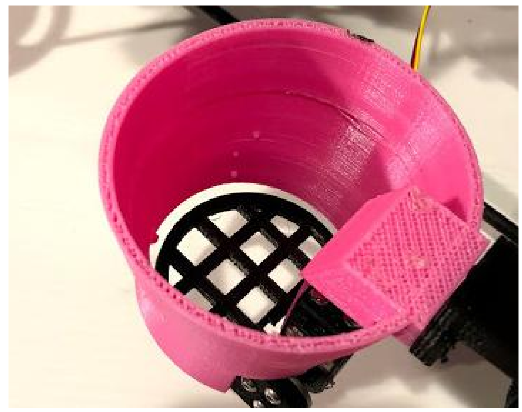


Figure 19: Material Dispenser

Metal Sensor - The metal sensor is used to detect metal cannon shells. The metal sensor is a magnet attached to a short string. When the the sensor is brought in close proximity to objects of interest, it will either continue to hang down or be attracted toward metal cannon shells. This difference is easily detected by monitoring two cameras.

Hook - The H2rOver is equipped with a versatile and simple hook to manipulate various objects it encounters. This hook is connected to a servo on the front of the ROV. The hook can be used in a number of missions; collecting water samples, moving rocks, transporting trash racks, and transporting a new reef ball.

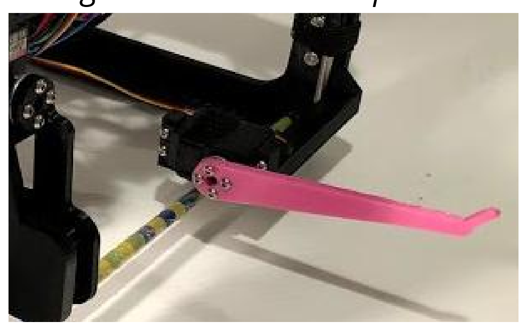


Figure 20: Hook

Temperature Sensor - The H2rOver utilizes a temperature probe to measure its environment. The probe is accurate to within 0.1℃.

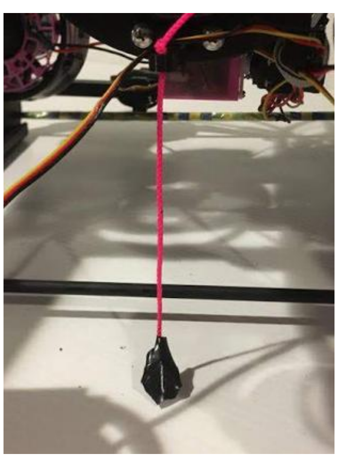


Figure 21: Metal Sensor

Figure 22: Temperature Sensor

Project Management

Another important improvement that Curiodyssea made was to create a detailed schedule to ensure that there was plenty of practice time before the competition. In order to get a head start and stay ahead of schedule, Curiodyssea began to plan prior to the release of the 2019 RFP. Curiodyssea knew that certain systems needed to be upgraded (see Design Rationale), so Curiodyssea focused on finding solutions for these systems. Curiodyssea divided work assignments on the ROV to have system leaders who specialized in each area of the ROV's development (electronics and control, chassis, propulsion, and cameras). Each project leader adhered to the Gantt chart, which ensured that development proceeded on time. It also allowed each project leader to focus on their respective system and become our in-house expert in that area. The deep insights gained by the project leaders increased the extent of our knowledge and made the overall team much stronger when developing the ROV.

Emails and texts were the primary means of communication. Notices were sent to all members of the team in order to keep everyone updated with meeting schedules. Additionally, these communications contained a small recap of what occurred at each meeting as well as an outline of our short-term goals.

Every time Curiodyssea met there was a recap of what was done last session (in case someone missed the previous meeting) and then Curiodyssea identified what had to be accomplished for the current session. During this time, members also were able to ask for assistance and help on assignments. Additionally, at the end of every meeting, a shopping list that would specify which parts needed to be purchased for the next session was compiled, so future meetings could be as productive as possible. This year, Curiodyssea continued to keep an inventory, tracking all available materials. Curiodyssea was thus easily able to determine when supplies needed replenishing.

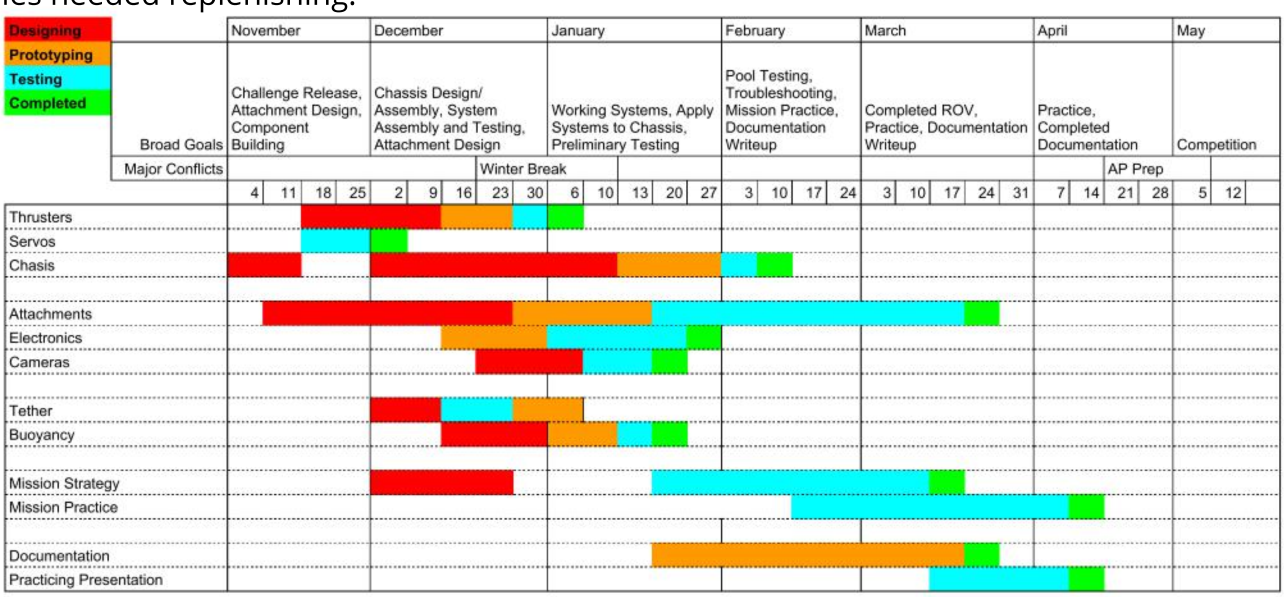


Figure 23: Company schedule

Safety

Safety is very important to Curiodyssea and our philosophy is to make sure that every aspect of building and operating our ROV is safe. Curiodyssea identified and implemented safety features and measures in three separate areas: on the ROV, in our workshop, and while testing in the pool to keep all members safe. These measures are outlined in our safety checklists (see next page).

Figure 24: Caution signs installed on the motors

The most hazardous parts of the ROV are the electrical system and the motors. Curiodyssea wanted to ensure that these parts would not cause any injuries during the building and operation of the ROV. Curiodyssea developed a series of safety protocols that were followed at all times. Curiodyssea inserted the required 25 amp fuse into the electrical system before testing any components. This, along with a master switch that could instantly cut power to the ROV, minimized potential power hazards. For motor safety, Curiodyssea built custom shrouds that covered all sides, a made sure motors were always securely mounted before running, checked for any wire entanglement, and required verbal confirmation between members before starting the motor operation. In addition, caution signs were installed on motors to warn of dangerous areas on the ROV.

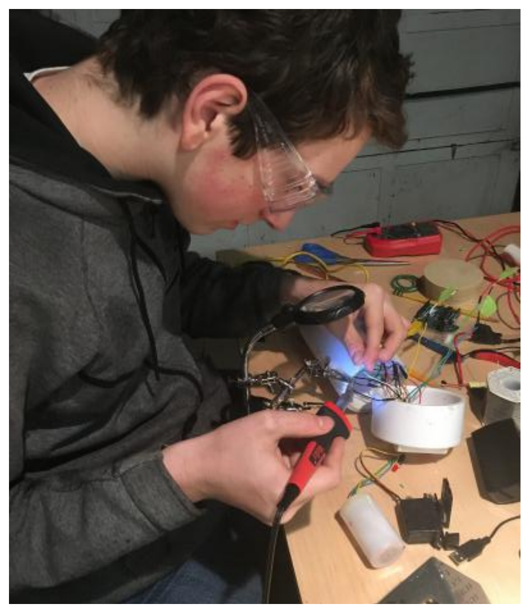


Figure 25: Curiodyssea team member carefully soldering wires

Curiodyssea also has a logbook to list safety incidents to help us track and analyze any problems. Curiodyssea is proud to say that it has been incident free for three years because of its respect for and implementation of the safety protocols.

Curiodyssea Safety Checklists

ROV Safety Features:

____ Tether strain relief

____ Shrouded and guarded motors

____ Color coded wires

____ Installed fuses

____ Safe and waterproofed wire connections

____ Caution signs installed on motors

____ Rounded and dull edges

Workshop Safety Measures:

____ Closed toe shoes while in workshop

____ Safety glasses when in the workshop

____ 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

____ All tether wires properly and securely connected

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

____ On-shore components secure

____ All moving parts are secured and clear of possible hazards

____ Verbally confirmed everyone is ready for operating the ROV

Testing and Troubleshooting Techniques

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

An example of this process is illustrated through the benthic species image recognition software. For the software Curiodyssea chose to custom train a neural network to do the image recognition. The neural network development iterations were saved in separate programs. For example, there was a version 2, version 2.1, and a version 3. This allowed us to revert back to older generations if the new changes were unsuccessful, and to use older generations as launch points for future testing. By preserving past iterations for future development, Curiodyssea could test many different variables in an efficient manner.

Another example was troubleshooting the Watertight Case. During pool testing, we noticed that the case was consistently accumulating a small pool of water over time, and the electronics were being damaged. Using iterative testing, Curiodyssea first ensured the case was watertight by replacing all penetrators in use with blanks. When the case was shown to be watertight, Curiodyssea then replaced the blank penetrators one by one until the faulty penetrators were installed and the leak returned. These connections were re-potted, and the watertight case was completely waterproof.

Figure 26: Electrical system troubleshooting

Curiodyssea used these scientific trouble shooting methods to prototype and test all of the systems and attachments thoroughly in the workshop before pool testing. The components were easier to replace or fix prior to being waterproofed, and Curiodyssea was able to identify issues before incorporating the system into the final ROV. Curiodyssea tested the cameras' fields of vision, specialty attachments, control of the electrical system, the motors (and their attached servos), 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. Curiodyssea first dry tested all installed systems in the workshop, and then began pool testing. Pool testing was done by submerging the ROV for increasing time intervals until Curiodyssea was confident all components were waterproof and working. Curiodyssea then configured navigation and attachment controls, and then finally practiced mission trials.

Future Improvements

Project Management - One future improvement that Curiodyssea would like to make is getting pool testing time earlier in the season. Curiodyssea began working on our ROV and mission-necessary parts as soon as the RFP was released, however, due to scheduling complications, Curiodyssea did not begin testing different components until late March. When testing parts, Curiodyssea learned that its theoretical calculations and reasoning were quite different from what actually happened. It was a challenge to troubleshoot and replace different parts and attachments needed for missions in order to get an operational ROV ready for mission practice. If Curiodyssea had testing time earlier in the year, these issues would have been fixed sooner and there would have more time to test.

Design Process - Another future improvement would be to have a better schematic for wiring. Curiodyssea made sure all the wires inside the watertight case were neatly organized, however, the wires outside of the case were not planned out well. The servos require three wires each, and this wiring was not originally accounted for. When the servos were wired, it led to a mess outside of the case which Curiodyssea was trying to avoid. In the future, the servos will be accounted for in the original design phase to make sure all features of the ROV are as neat as possible.

Challenges

Technical - One technical challenge that Curiodyssea encountered was making our ROV stable. During the first pool test, when the ROV was propelled forward, it would go to the surface and the front would jut out of the water. When moving backwards, the rear of the ROV would stick out of the water. Curiodyssea identified the source of this issue to be a mismatch between the center of thrust and center of mass, causing the motors to generate a torque on the ROV. It was determined that the center of mass of the ROV (by balancing the ROV on the edge of a yardstick) was above the horizontal motors (confirming that this was the issue). In order to fix this, the center of mass was moved downwards by adding rebar to the bottom of the ROV. However, knowing that the rebar could make the ROV too heavy and limit mobility, it was also decided to move the horizontal motors upwards so that they would be on the same horizontal plane as the center of mass.

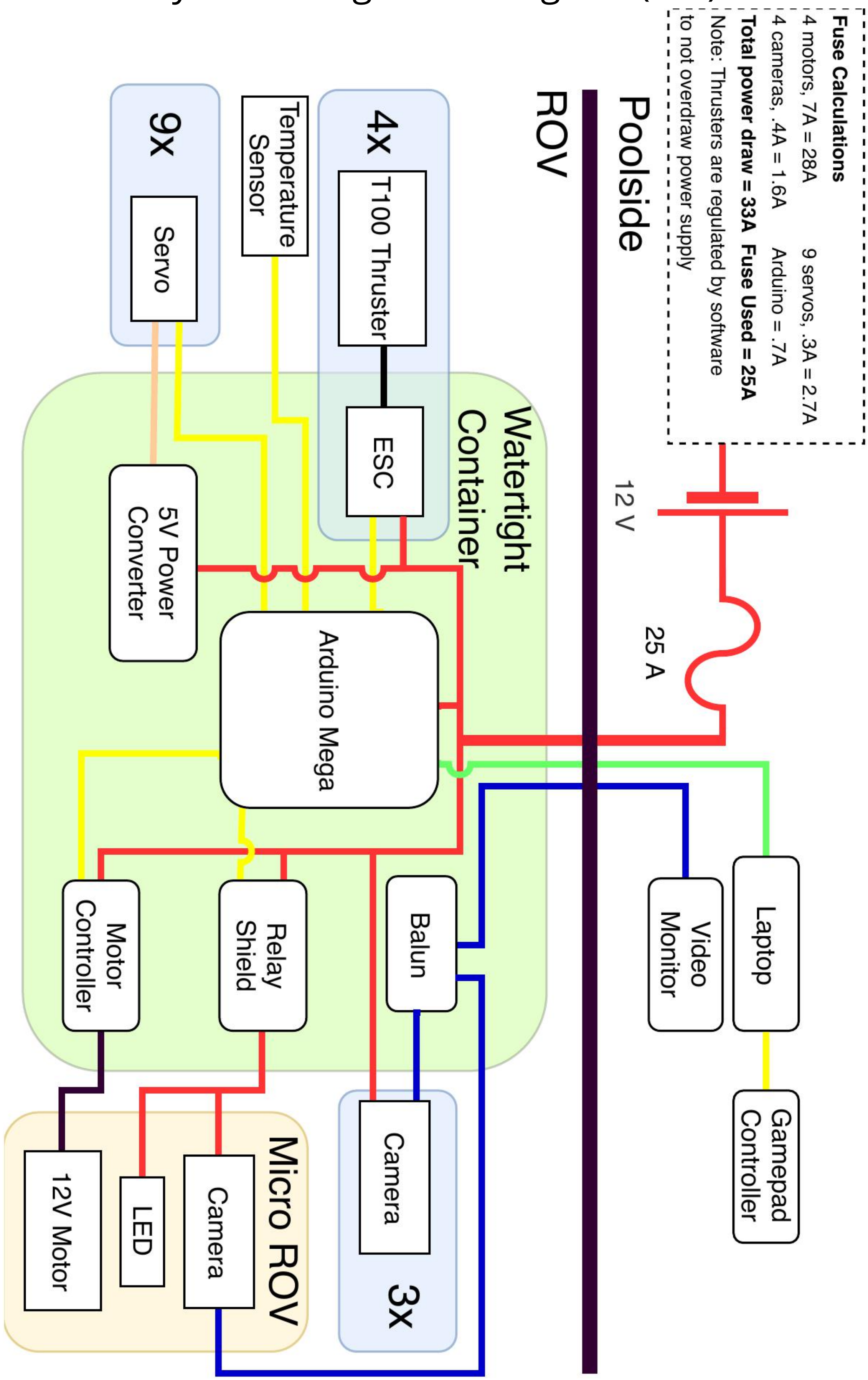
Interpersonal/Organizational: One significant organizational challenge that Curiodyssea encountered was finding mutually agreeable times to meet. Curiodyssea is a small five person team with three high school seniors. Time consuming college applications made it extremely difficult for seniors to meet from November through December. In addition, team members had sports or other extracurriculars in addition to school work, which created conflicting schedules for meeting times. In order to remedy this issue, meetings were held on Saturdays and Sundays and members would come whenever they could and work on their designated system. If these dates did not work, then team members worked independently to develop their own systems.

Lessons Learned

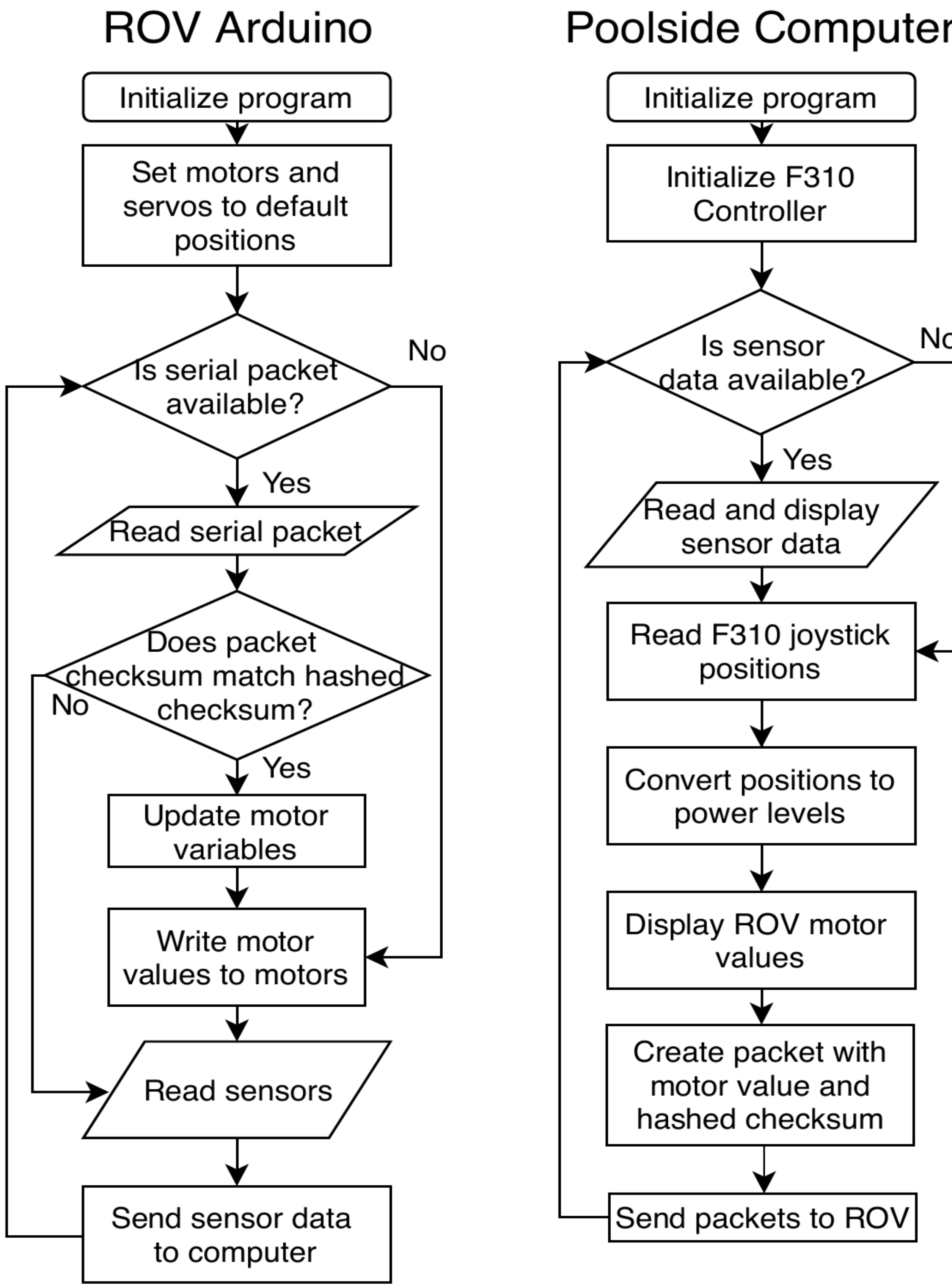
Technical: In previous years, Curiodyssea has opted to use more traditional system designs and has avoided making radical changes between different iterations of ROVs. This design philosophy allowed Curiodyssea to focus on designing high quality components instead of investing many hours on more risky innovative designs. This year, Curiodyssea decided to explore new designs since its team members had sufficient expertise and experience to succeed. Curiodyssea invested time and resources into creating a gimballed four motor propulsion system instead of the standard six motor system Curiodyssea used on previous ROVs. Curiodyssea was cognizant that the gimballed design had the potential to be more successful than a traditional design, but it would be significantly more difficult to construct. A large amount of time was put into developing the new system and solving problems related to it. After much trial and error, the system worked with minimal bugs. From this experience Curiodyssea learned that it is worth following ideas that are risky but have the potential for major technical and performance innovation.

Interpersonal/Management: This year, Curiodyssea operated with the minimal amount of mentor assistance as possible. Last year, our mentors assisted us in coordinating meeting times and keeping us on topic. Wanting to take on more leadership responsibility, Curiodyssea took entire ownership of scheduling when to work on the ROV and maintaining focus on the task at hand. Through this experience, Curiodyssea learned to function more autonomously as more responsibility was assumed in all aspects of the program.

System Integration Diagram (SID)



Software Flow Charts



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For questions, comments, or feedback, please contact us at Curiodyssea@gmail.com