Technical Documentation Report

RoseVG Robotics

For Rose-Hulman Institute of Technology

Terre Haute, IN, USA

Scooter

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Abstract

We are RoseVG Robotics, a team of 14 students from Rose-Hulman Institute of Technology. We are excited to present our most recent remotely operated vehicle (ROV), Scooter. Scooter is a small, light, cost effective and innovative ROV capable of performing manipulation and observation tasks in underwater scenarios. Scooter is the culmination of a three year journey of learning and problem solving by all of our members, and represents RoseVG's design principles, teamwork, project management philosophy, and prioritization of personnel safety and growth. We at RoseVG Robotics hope you enjoy this story of Scooter's development, and we are excited to put it to the test performing difficult subsea tasks at the 2025 MATE ROV Competition World Championship and beyond!

Contents

Teamwork

Company Overview

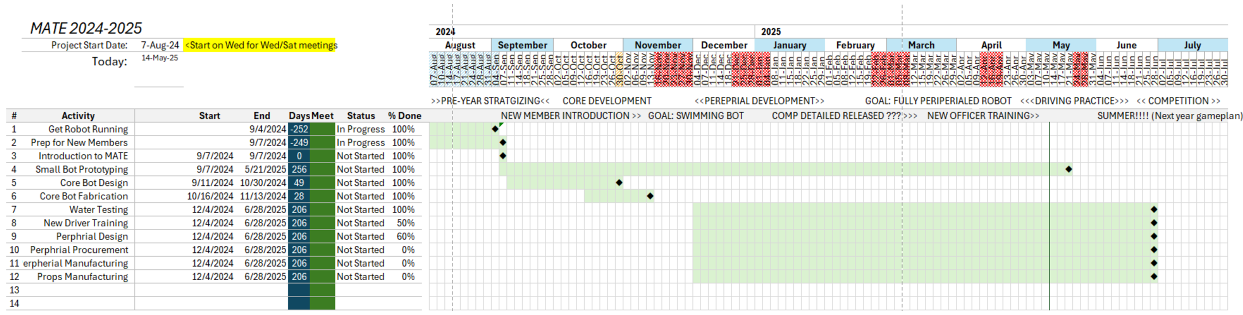
RoseVG Robotics is an undergraduate student team that is part of the general Robotics organization at Rose-Hulman Institute of Technology. The Robotics organization is managed by an executive board, otherwise known as the E-Board, which oversees the organization and allocates resources to teams as needed. RoseVG Robotics consists of 12 team members who are divided between 3 teams: mechanical, electrical, and software. RoseVG Robotics' CEO is in charge of leading the company, setting its priorities, and ensuring that each team has tasks to work on throughout the meeting. Each of the teams oversees completing the tasks assigned to them by the CEO. Each of these teams has a lead who manages their team and is an officer of RoseVG Robotics. The officers also include the team's treasurer and secretary, who oversee the team's budget and documentation, respectively. As officers, they oversee sharing the responsibility of leading the team members and attending officer meetings, separate from the all-team meetings, to report on their team's progress.

Project Management

RoseVG Robotics follows a weekly development cycle. The cycle starts on Tuesday during the officer-advisor meeting held with the team mentor. During these meetings, the officers go over progress made in the previous week, assess the remaining tasks, add tasks that need to be completed and by what time assign tasks to the teams, discuss how our timeline needs to be revised according to the progress that was made. After the officer meeting, the all-teams meetings are held on Wednesday and Saturday where the team leads organize their employees to work on the tasks designated to them during the officer meeting. The employees spend the meeting working to carry out the tasks assigned to them by the team leads. The week concludes on Saturday after the all-team meeting, and the development cycle starts again at the officer meeting on Tuesday.

For RoseVG Robotics' project management tools, the company uses Discord for general communications among its employees and its officers, having many channels for specific lines of communication. Additionally, Notion is used to organize the different tools and keep the documentation in one place, and Github is used for file-sharing and software version control.

Project Schedule



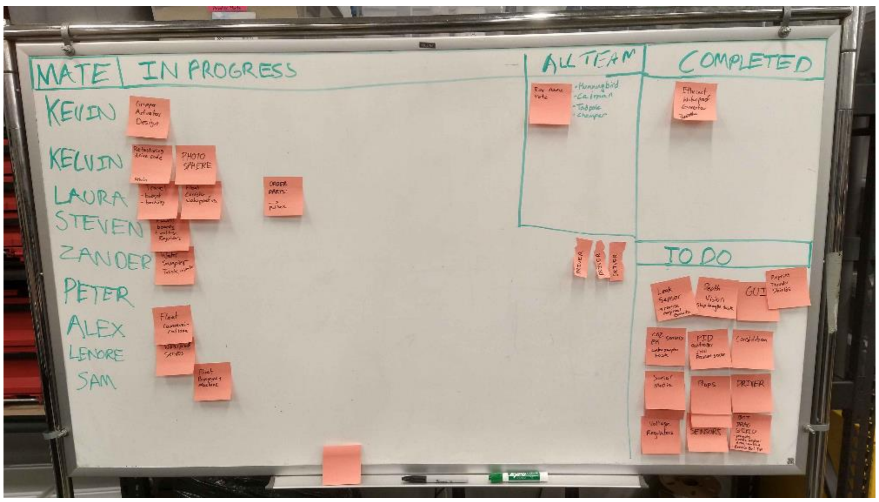
MATE 2024-2025

Project Start Date: 7-Aug-24 <Start on Wed for Wed/Sat meetings

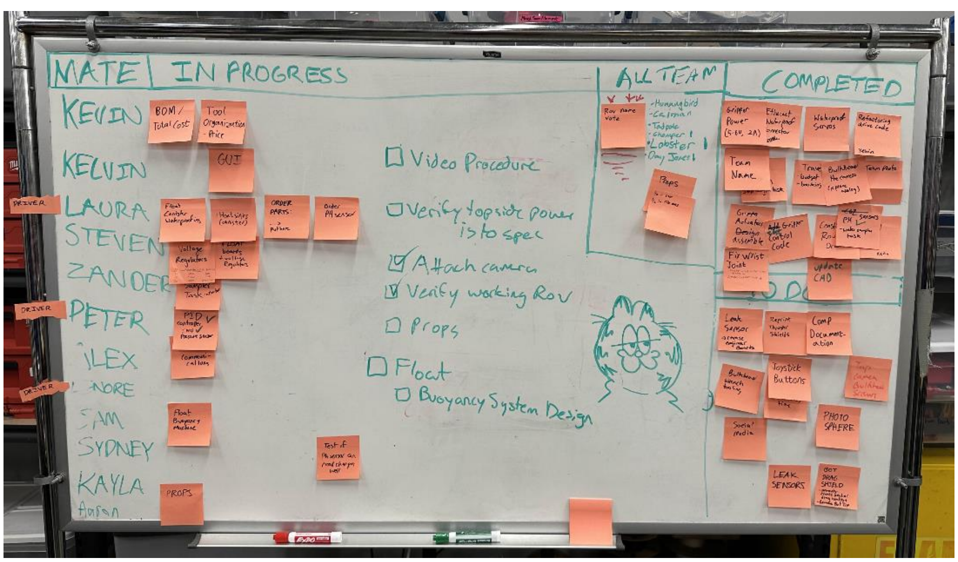
Today: 14-May-25

#	Activity	Start	End	Days	Meet	Status	% Done
1	Get Robot Running		9/4/2024	-252		In Progress	100%
2	Prep for New Members		9/7/2024	-249		In Progress	100%
3	Introduction to MATE	9/7/2024	9/7/2024	0		Not Started	100%
4	Small Bot Prototyping	9/7/2024	5/21/2025	256		Not Started	100%
5	Core Bot Design	9/11/2024	10/30/2024	49		Not Started	100%
6	Core Bot Fabrication	10/16/2024	11/13/2024	28		Not Started	100%
7	Water Testing	12/4/2024	6/28/2025	206		Not Started	100%
8	New Driver Training	12/4/2024	6/28/2025	206		Not Started	50%
9	Perphrial Design	12/4/2024	6/28/2025	206		Not Started	60%
10	Perphrial Procurement	12/4/2024	6/28/2025	206		Not Started	0%
11	erpherial Manufacturing	12/4/2024	6/28/2025	206		Not Started	0%
12	Props Manufacturing	12/4/2024	6/28/2025	206		Not Started	0%
13							
14							

Our schedule, as the year goes on we shift from development to testing and practice



Task organization early in the development process



Task organization late in the development process

Design Rationale

Scooter was designed in accordance with RoseVG Robotics' design principles and the requirements of the 2025 MATE ROV Competition missions. This section will outline our design principles and how they led to the design requirements for Scooter. It will discuss the overall design of Scooter, then go into detail on each subsystem.

RoseVG Robotics Design Principles

RoseVG Robotics has six main design principles, which are as follows:

DP1 - Smaller is better. Smaller, less bulky ROVs and ROV components are safer and easier to handle by personnel and perform better in tight subsea spaces.

DP2 - Simplicity is better. All else equal, simpler architectures and mechanisms are superior to more complex ones; they are more reliable and easier to service (DP5). DP2 may be violated in cases where a more complex system provides significantly higher performance or reliability or enhanced learning opportunities for students.

DP3 - Solve problems physically first. Solutions that are more physically complex are acceptable if they reduce programming complexity a proportional amount. Do not wantonly increase programming complexity by making physical design changes.

DP4 - Prioritize versatility while remaining competitive in required tasks. Designs that are performant at many tasks are preferable to designs that are performant in one task only; subsea operations can throw unanticipated situations, and higher versatility is a higher likelihood of managing those situations.

DP5 - Ease of service and assembly is better. Mistakes will happen, and technicians are imperfect. The less steps there are to service and assemble components, the faster and easier it will be to assemble and repair the product.

DP6 - Easier to source is better. Easily procurable components are preferable to more niche, esoteric ones.

In cases where two design principles are at odds, a holistic decision making process should be utilized to determine the principle that should receive higher priority.

These design principles, along with the requirements for known MATE ROV Competition games and lessons we learned from our previous products guided the specific design requirements for the development of Scooter.

Scooter Design Requirements

The initial design requirements laid out for Scooter are as follows:

DR1 - Small enough for 1-person carry. Scooter shall be small and light enough to be carried by one person. This requirement directly follows from DP1 and from our experiences developing Duck, a large ROV that could not be carried by one person.

DR2 - Six Degrees of Freedom (DoF) of Motion Underwater. Scooter shall be capable of moving in all 6 DoF of physical motion: 3 dimensions of translation (surge, sway and depth) and 3 dimensions of rotation (roll, pitch and yaw).

DR3 - Simple kinematics and control. Scooter shall be physically designed such that RoseVG's software team finds it reasonably easy to write code for thruster kinematics and dynamic control. This follows directly from DP3.

DR3.1: Known thruster kinematics. Scooter shall use a thruster configuration that is well known to be easy to use with minimal programming complexity. This follows from DP3 and DP2, and is important for rapid testing / shakedown before advanced kinematics algorithms are written.

DR3.2 - Center of buoyancy near, but slightly above center of mass. Placing the center of buoyancy (CoB; the point in the ROV that the buoyant force acts on) slightly above the center of mass (CoM; the point on the ROV that gravity acts on) will make Scooter level naturally, minimizing effort for dynamic leveling control systems (DP3). Placing the two close together is also important, since Scooter may have to tilt itself for some games (DP4), a task that is more difficult the farther apart the CoB and CoM are.

DR3.3 - Center of thrust near center of drag (prioritizing surge direction). Placing the center of thrust near the center of drag will allow Scooter to move in a straight line in the surge direction without drag forces causing the robot to tilt up or down. This minimizes effort from control systems (DP2, DP4)

DR4 - Prioritize surge speed and sway precision. RoseVG Robotics has determined that for most scenarios, forward-backward motion (surge) is typically higher speed, and left-right motion should be slower and more precise. Scooter's thruster and frame configuration shall prioritize surge speed and sway precision. (DP4)

DR5 - Slightly Positively Buoyant. Scooter shall be slightly positively buoyant, and therefore will float to the surface when power is lost without requiring very much power to keep itself at a certain depth.

Several design requirements were laid out for the manipulators of Scooter:

DRM6 - Active manipulators should be few and versatile. One more complex active manipulator that can do multiple tasks is preferable to multiple simpler active manipulators that can do one task each. While this appears to violate DP5 and DP2, RoseVG Robotics has determined that the active component tends to be the least reliable component of any manipulator, so minimizing the number of active manipulators improves serviceability and reduces complexity on whole despite the existing manipulators being more complex.

DRM7 - Manipulator should be able to securely grip long objects at any orientation and in a range of sizes. Many MATE ROV Competition mission requirements include manipulating PVC pipes of varying sizes and orientation, so Scooter's manipulator should be able to do this. (DP4)

DRM8 - Manipulators should be durable and robust to impacts, bumps, and knocks. Running into objects when in or out of the water should not damage manipulators.

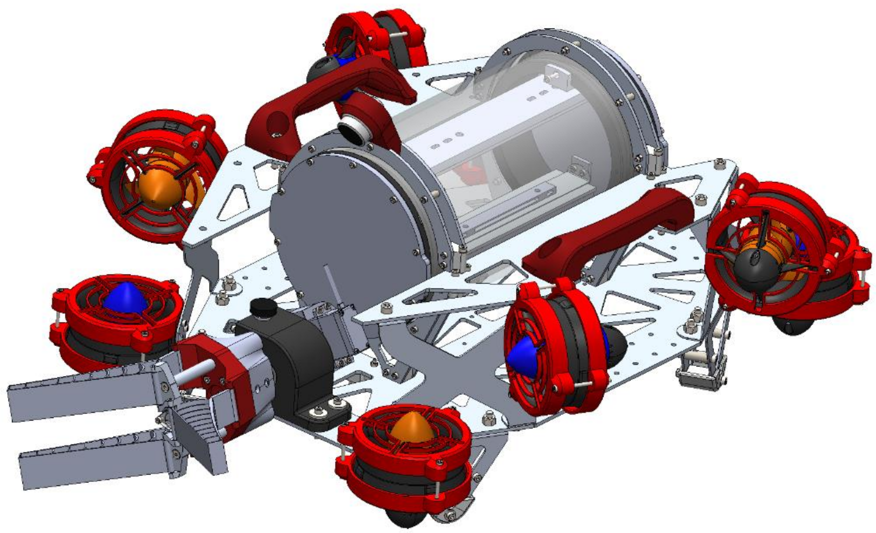
DRM9 - Manipulators should be forgiving of misalignment and imprecision in ROV motion. Quick and precise motion underwater is challenging, so the manipulator should work from multiple angles and positions. (DP3)

DRM10 - Manipulators should be manufacturable in-house, especially components that are likely to wear out. Manipulators are a high-use and high stress component that is vital to the functionality of Scooter. Therefore, it is vital that components are easy to source and replace per DP6.

These design requirements were used to guide and evaluate our brainstorming and decision making processes.

Final Design - Scooter

Scooter is a small, light, and reliable ROV capable of performing manipulation and observation tasks in underwater scenarios. It is comprised of three main subsystems: the drive system, the manipulator system and the electrical system.



A computer rendering of the SOLIDWORKS model of Scooter, final design

Drive System / Chassis

Scooter's drive system comprises everything that effects and is required for ROV motion underwater. This includes the thrusters and thruster configuration, the frame layout, and drive control systems.

Frame Layout

Scooter's frame was carefully designed to meet our design requirements for size (DR1), center of buoyancy (DR3.2), and center of drag (DR3.3). The frame places a BlueRobotics 6" canister at the center and slightly above; since the canister is a significant component of Scooter's buoyancy, this choice puts the center of buoyancy slightly above the center of mass for natural stability (DR3.2). The small canister allowed us to make the frame less than 580mm wide and 630mm long, making it easier to meet our design requirement for small size and weight (DR1).

Thrusters / Thruster Configuration

Scooter uses 8 BlueRobotics T200 thrusters; four in a vectored horizontal thruster configuration and four vertical thrusters. This allows Scooter to quickly move in any direction and rotate about any axis (DR2). This configuration makes commonly commanded motions (surge, sway, yaw) use the horizontal thrusters, and commonly automated motions (roll, pitch, depth) use the vertical thrusters. This decoupling allows for simple motion kinematics that RoseVG's software team was able to implement quickly (DR3.1).

The vertical thrusters are spaced far apart to increase the roll/pitch torque they can provide. The horizontal thrusters are placed vertically near the estimated center of drag in order to minimize rotation when moving forward at speed (DR3.3), and they are angled to provide more thrust in the surge (forward) direction (DR4).

Orientation Control System

Scooter features a custom proportional-integral-derivative (PID) feedback controller that keeps it at a target orientation (roll, pitch, yaw) when in the water. An onboard Inertial Measurement Unit (IMU) detects the direction of Earth's gravitational field to determine the orientation of the ROV. The PID controller can control thruster input to keep the ROV at the target orientation. While the current iteration of the system keeps Scooter level when driving, future iterations may allow for holding other orientations as the mission requires. A code snippet of Scooter's PID controller update function is below.

```
float PID::update(float setpoint, float measured) {
  error = measured - setpoint; // "how far off you are"
  dt = (millis() - lastMillis)/1000.0; // Used for integral and derivative

  // de/dt Derivative term. Acts as a damper by resisting change in error
  d = kd*((error - lastError) / dt);

  // Proportional term. Resists error directly.
  p = kp*error;

  // integral(error, dt) ... Trapezoid rule integral. Look it up
  integral += (((error - lastError)/2) + lastError)*dt;

  // Bound the integral so we don't have windup
  integral = min(integral, maxIntegral);
  integral = max(integral, -maxIntegral);
  i = ki*(integral); // integral

  lastMillis = millis();
  lastError = error;
  return p+i+d;
}
```

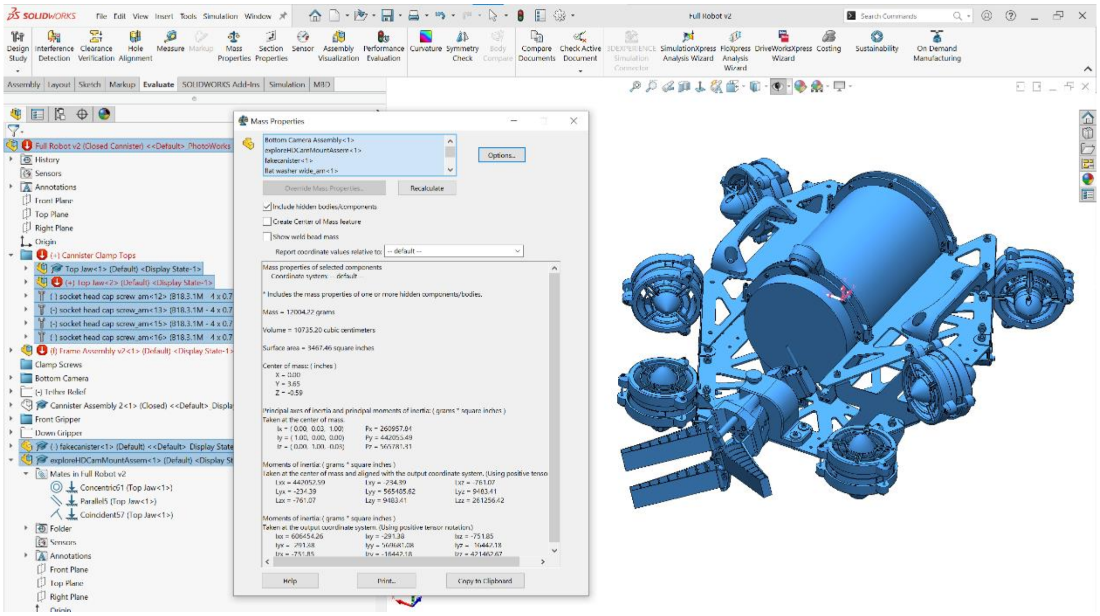
Drive System / Chassis Design Process

Scooter's drive system was designed as an incremental improvement (with respect to design requirements DR1-DR4) on our previous generation product, Duck. This incremental design process is summarized in the following table.

Subsystem	Duck (Previous Gen)	Scooter	Improvement and Motivation
Frame Layout			
Canister Size	BlueRobotics 8" Canister.	BlueRobotics 6" Canister.	Smaller canister allows for a smaller frame (DR1).
Canister Position	Vertical, centered on frame, higher than frame center	Horizontal, centered on frame, close to frame center	Placing the canister horizontally and closer to frame center makes center of buoyancy much closer to center of mass. (DR3.2)
Thrusters			
Thruster Type	T200 Thrusters	T200 Thrusters	T200 thrusters were determined to meet all design requirements.
Thruster Configuration	4x vectored horizontal, 4x vertical	4x vectored horizontal (biased for forward motion), 4x vertical	Duck's thruster setup was well understood (DR3.1) and provided motion in all directions (DR2). The only change was to bias thruster directions for forward motion (DR4)
Orientation Control	Center of buoyancy significantly above center of mass	PID Control System	While Duck remained stable and upright when stationary in the water, it tilted significantly while in motion. A PID control system was judged to be more robust in this situation.

Drive System / Chassis - Buoyancy

To meet design requirement DR5 (slightly neutrally buoyant), we left space on the bottom of Scooter's frame for buoyancy control such as ballast or floats. In order to estimate how much positive or negative buoyancy we need to add, estimated Scooter's buoyancy. Buoyant force F_b is equal to the weight of displaced water, which is equal to the volume of displaced water V multiplied by density of water ρ. [1] The volume of displaced water was estimated using SOLIDWORKS mass properties as in the figure below.



A volume displacement and center of mass analysis in SOLIDWORKS.

The above mass properties analysis shows that Scooter has a volume of approximately 10735cc. Multiplying this by the density of water ~1g/cc yields a buoyant force of 10735gf or about 10.7kgf. Scooter was weighed at w = 11.7kg, leading to a net buoyancy force of $Fb - w$ = -1kgf. To meet our design requirement of slight positive buoyancy (DR5), we added foam blocks with just over 1kgf of buoyancy to Scooter's frame, bringing net buoyant force to just over 0kgf.

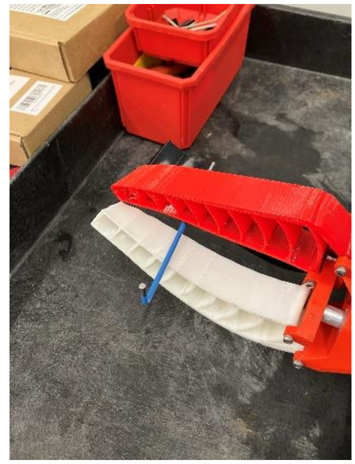
Manipulator System

Scooter's manipulator system is a high performance gripper developed by RoseVG to be able to grasp long objects of varying shapes and at varying angles, as is required by the MATE competition missions and our requirement DRM7. It has three compliant fingers that operate on parallel planes and cross each other when closed. It is mounted on a wrist joint allowing unlimited rotation. Its high-wear parts such as gripper fingers and worm gear can be 3D printed and easily replaced in the field, minimizing cost and downtime.

Compliant Fingers

The gripper in the open position

The gripper grabbing a large box in the vertical direction

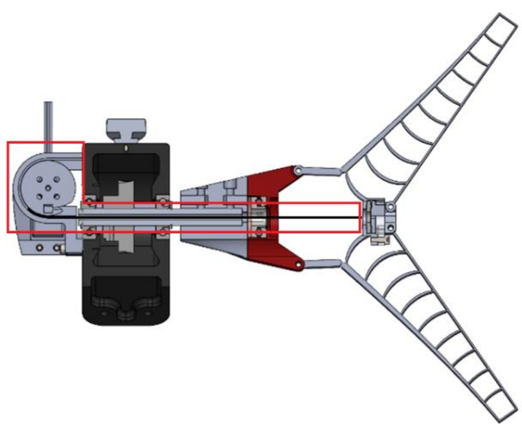


The gripper grabbing a small thin item horizontally

Scooter's gripper system uses three compliant fingers as shown to grip objects. Because of the crossing geometry of the fingers, very thin objects can be gripped, and when gripping large objects, the fingers wrap around the objects to resist them pulling out of the gripper. (DRM7)

Using compliant fingers has several advantages over rigid grippers. Firstly, they are more durable than rigid grippers, since harsh impacts will cause the fingers to bend without breakage. Secondly, they are less likely to damage small or delicate objects; excessive grip force will cause the fingers to wrap around the object, increasing the surface area of finger against object and spreading out the grip force.

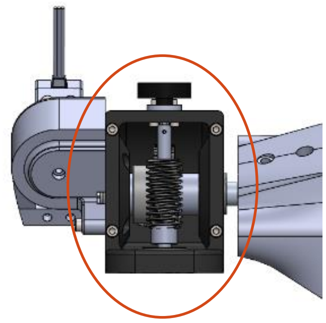
Actuation System



A figure showing the gripper mechanism bowden cable mechanism

Scooter's fingers are attached to a sliding mechanism as shown above. A thin stainless steel cable is attached to the sliding mechanism and is pulled by a waterproof servo winch. When the winch pulls the cable, the slide moves inwards, resulting in a gripping motion from the fingers. When the winch spools out, the slide is pushed outwards by the springback caused by a slight deformation of the fingers during gripping.

Wrist Joint



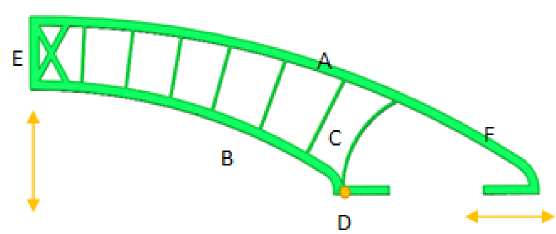
A view internal of the wrist gearbox including a worm gear, driven by a motor

In order for Scooter's gripper to rotate continuously while grabbing, the gripper mechanism is mounted on a wrist joint as highlighted above. The wrist joint motor is attached to the hollow shaft with a worm gearset, and the entire gripper assembly is mounted on the shaft. The actuation cable runs from the servo winch on the stationary side of the wrist joint to the gripper slide on the moving side; to keep the cable from twisting, it is attached to the slide with a small integrated bearing that allows it to apply axial force while the gripper rotates freely.

Manipulator System Design Process: Fingers

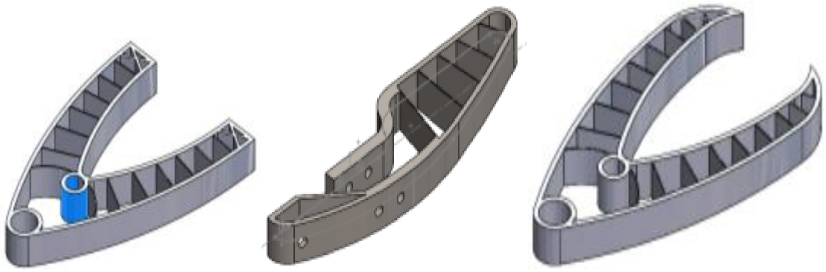
The fingers for Scooter's compliant manipulator system were designed iteratively in two main phases. The first phase of this design process was an exploratory phase, where RoseVG's gripper prototyping team brainstormed, prototyped and evaluated dozens of compliant gripper shapes. The second phase was a design phase, where the best performing prototypes were refined and developed into reliable and performant final products.

The exploration phase started with a brainstorming of many possible gripper designs, as seen below. These designs were 2D extruded shapes intended to be printed in thermoplastic polyurethane (TPU) on a desktop 3D printer. These designs were all derivatives of a base design we call a ‘finger’ of a gripper, which converts linear motion to a gripping motion.

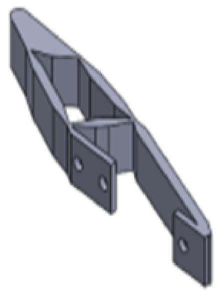


A finger of the rov with important locations denoted

This 'finger' consists of two sides (A and B), which can move sideways relative to each other. Flaps C ensure that A remains a fixed distance from B without hindering sideways motion.



Prototypes of the flexible gripper

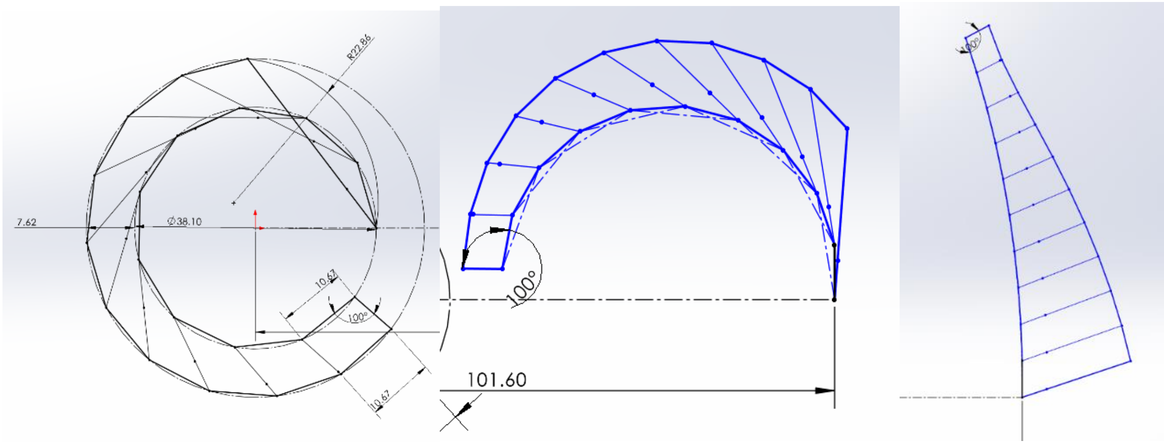


The above designs were prototyped and evaluated to gain a better understanding of their behavior:

A prototype finger in its steady state

A finger deforming around a solid object

For the second phase, we used what we'd learned from the exploration phase to design gripper fingers that would meet design requirement DRM7 (securely grip long objects). The finger design we ultimately chose was the "wrapping finger", which was designed to distribute force evenly while gripping a circular object. It was modeled as a series of rigid linkages wrapped around a cylinder, which were then "unfurled," resulting in the final gripper shape.

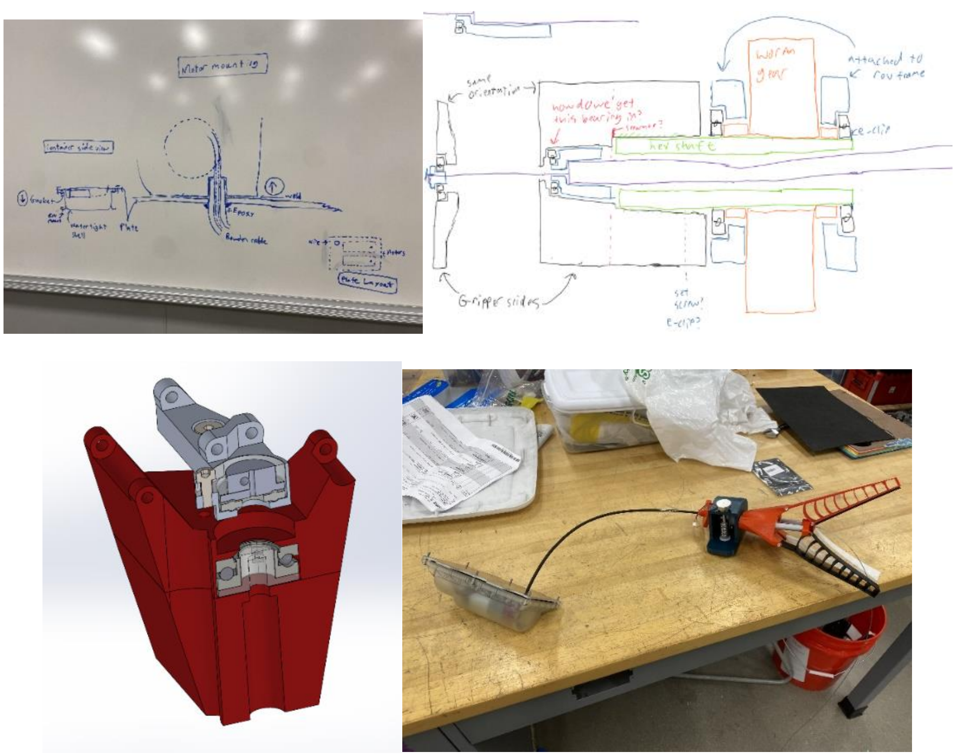


Demonstration of the flexible behavior in the Solidworks sketch, the underlying behavior of this gripper finger

Manipulator System Design Process: Actuation and Wrist Joint

To ease development and reduce variables, all finger designs converted linear motion to gripping motion, giving Scooter's gripper actuation and wrist joint system a simple design requirement: provide axial force while being able to control rotation. This allowed the actuation and wrist system to be easily developed alongside the gripper fingers.

Several linear motion systems were considered, but the only system that yielded a prototype compatible with wrist motion was a cable tension system. This system started out as rough sketches and developed into a full-scale prototype consisting of a brushed motor in a separate waterproof canister. The cable exited the separate canister through a sheath before entering the gripper slide.



Drawings and prototypes of Scooter's manipulator actuation and wrist joint system.

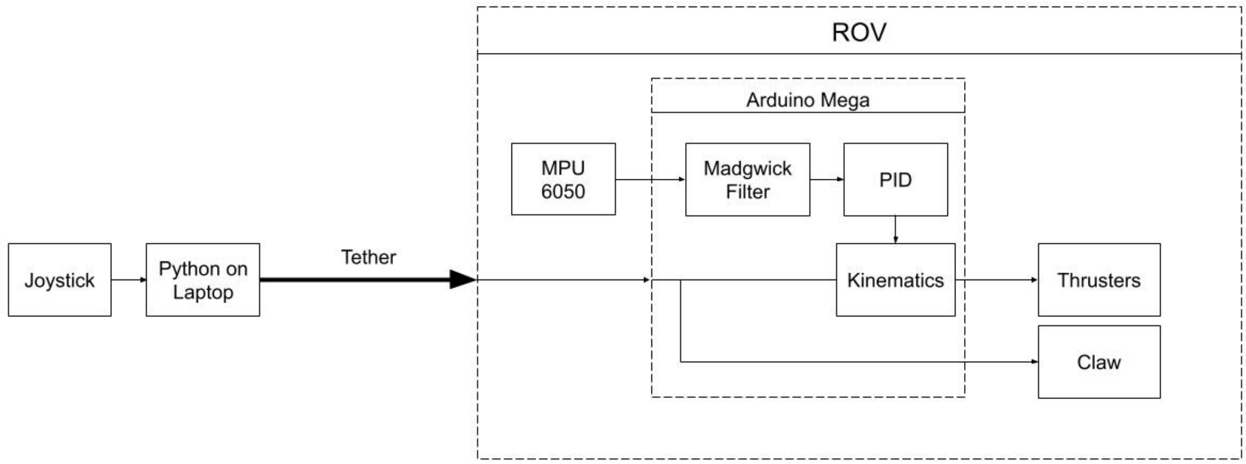
We found that water was able to ingress through the cable sheath, so the actuation system was switched to a single waterproof servo winch with water being able to access the entire cable.

Electrical System

Scooter's electrical system comprises its onboard microcontroller, its sensors, its power electronics, its camera systems, its waterproofing systems, and its tether. The control and power electronics are presented diagrammatically in the SID, and this section is a more in depth overview of all systems.

Control Electronics

Scooter's onboard microcontroller is an Arduino Mega 2560. It is easily obtainable (DP6), easy to use/debug (DP2, DP5) and can run Scooter's kinematic code, communication code, and control systems code. The Mega 2560 runs an Arduino sketch that receives serial input from the drive station and reads acceleration and angular acceleration from an InvenSense MPU6050 inertial measurement unit (IMU). It uses a Madgwick filter on the accleration data to calculate Scooter's orientation in the water, then uses a PID controller to calculate an appropriate force to return itself to level. Finally, It performs force kinematics to determine how to run Scooter's thrusters to produce the desired direction of force.



High-level diagram of Scooter's kinematic, communication and control systems code

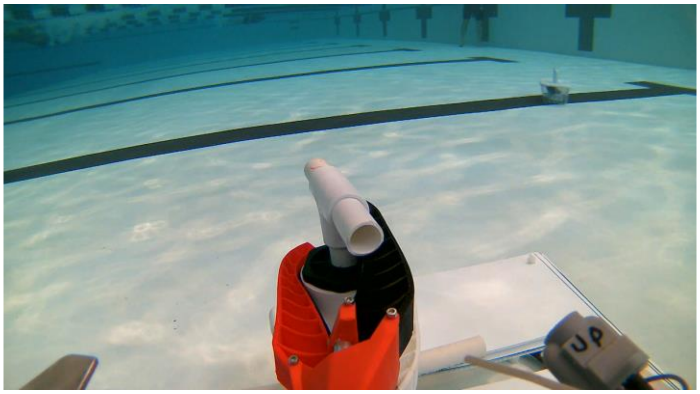
Scooter's Mega 2560 is connected to other electrical subsystems using a protoboard shield with soldered connectors. Wires on the protoboard are easily traceable to the Mega 2560's pins, allowing for easy maintenance and debugging.

Power Electronics

As depicted in Appendix: S, Scooter's power electronics consist of switching voltage regulators to provide voltages of 12V and 5V inside the canister, and brushless ESCs to commutate brushless motors such as thrusters. Onboard 12V is presented on a screw terminal block, allowing for easy wire tracing and service. BlueRobotics Basic ESCs are used to commutate all 8 thrusters and the manipulator wrist joint motor.

Camera Systems

Scooter has two cameras: a drive camera and a manipulator positioning camera. The drive camera, an ExploreHD 3.0 USB waterproof camera, is centered with a view of the manipulator system and the entire front of the ROV. This view was determined to be helpful for initial lining up with a task and for navigation under the water. The manipulator positioning camera is a potted RunCam Nano V2 mounted to the right of the manipulator. It is mounted close to the manipulator but has a wide field of view, allowing the operator to easily see the manipulator's immediate surroundings.



View from drive camera

View from manipulator camera

Tether

Scooter's tether supplies power from the surface and enables communication with the drive station. It consists of two sets of two 12 AWG wires to carry 48V power, and one cat5e ethernet cable for communication. It is contained in an expandable sleeving wire loom for protection against abrasion, and is strain relieved on Scooter's frame and on the topside drive station. It enters Scooter's canister through a SubConn Circular 4-contact connector (power) and a SubConn Micro Circular 8-contact connector (ethernet).

Electrical System Design Process

Scooter's electrical/control system was designed around RoseVG's design principles DP2 (simplicity) and DP5 (ease of service). The Arduino Mega 2560 was chosen over our standard TI LaunchPad C2000 for the onboard microcontroller because it had more developed libraries and a simpler learning curve. Additionally, recent curriculum changes at RoseVG's parent institution Rose-Hulman Institute of Technology mean that Arduino programming gets taught sophomore year or earlier for several majors, meaning that RoseVG members on whole will be able to contribute to code design and debugging much earlier.

Safety

PHILOSOPHY

Safety is first and foremost in RoseVG Robotics’s priority regarding our work environment. By ensuring that the personal safety of all our employees is secured and the proper safety features are installed on the ROV, we can minimize the chances of accidents happening. Furthermore, we believe that a safe work environment will improve the morale, productivity, and security of our employees, knowing that they don’t have to be overly cautious about every little detail when working on the ROV.

PERSONAL SAFETY STANDARDS

RoseVGRobotics has safety standards that each employee is required to follow prior to entering the workspace. First, there's a training course that all employees have to complete to gain access to the building where the workspace is. This includes learning and taking a quiz on wearing proper PPE, including long pants, eye protection, and closed-toe shoes. It also covers procedures to follow in case of an emergency, how to organize materials and equipment in the workspace, how to properly operate equipment, and how to dispose of different types of waste. After passing this course, employees are required to follow the guidelines explained during training and maintain a neat and safe workspace. Along with our priority of personal safety, we also have an anti-harassment policy that gives the company the ability to kick out any members during the year if they're causing trouble. This policy aims to give our employees the security to attend all our meetings without the worry that anyone will take away from the experience of working for this company.

ROV SAFETY FEATURES

Scooter was made with safety and ease of interaction in mind throughout its design and building process. Starting with its materials, we made sure to have no sharp edges on any part of Scooter by sanding down the materials and designing the corners to have fillets and chamfers to round out the edges further. On the electrical side, we made sure not to have any exposed wires on any electrical components on Scooter. Furthermore, any area that could be exposed to electricity that isn't a wire is covered with electrical tape to ensure it doesn't come into contact with any metal parts. When we get ready to operate Scooter, we have covers on the propellers at all times that they're not in use. Lastly, we always call out before turning on Scooter to make sure that everyone in the vicinity knows that the thrusters will be getting turned on and to take extra caution when approaching that area of the workspace.

Start checklist

1. Seal the ROV
    a. Ensure no wires are caught in between the bulkhead and lid
    b. Ensure all O-Rings are in place and lubricated
    c. Ensure all thumb screws on both sides are tight
2. Power the ROV
    a. Have one worker monitor the ROV while a second flips the power switch
    b. If any smoke appears immediately stop
3. Dry Systems Test
    a. Test all 8 motors, the claw, and wrist by moving the joystick
    b. Test PID by rolling the ROV
4. Putting ROV in Water
    a. Slowly place the ROV in the water while watching for breaches
    b. Take it out and inspect for water
    c. Repeat for longer amounts of time in the water
5. Waterproof testing
    a. Leave ROV in water for several minutes while performing typical operations
    b. Examine closely for any leaks
6. ROV Operaion
    a. The ROV should be fully operational

Critical Analysis

Test methodology:

- Turn on the robot and do a quick check on land to make sure core components work such as the claw, motors, and camera
- Turn off the robot before leaving it underwater for around 5 minutes to check for leaks.
- Turn back on the robot and begin testing on an objective of our choosing (one at a time testing procedure).
- Make any changes to the code and upload through GitHub. Remove the robot from the water during this time period.

Troubleshooting strategies:

Elimination method. If something doesn't work, isolate the source of the failure by figuring out where the failure isn't occurring. For example, when troubleshooting cameras not working, first we would test whether or not the cameras would work directly connected to the computer, then over an cat5e cable, then over the tether, then over a USB hub. If at any point the camera stops working, isolate the error further from there. Are wires corroded? Are the connections broken? Does the camera need more power?

Prototyping and changes in design (engineering design process):

Our engineering design process consists of three main phases: brainstorming, design, prototyping, and evaluation. Brainstorming sessions are open and multidisciplinary, where all ideas are welcome and creativity is encouraged. Design entails culling brainstorms and developing them into concepts worth prototyping, with an aim of learning as much as possible from each valuable prototype. Finally, prototypes are evaluated, and the lessons learned are fed back into a more focused brainstorming session for the next iteration of the engineering cycle.

An example of this is with how Scooter's gripper evolved. We started off with designing multiple different gripper designs and comparing their pros and cons with each other. Once we sorted out the best possible design(s), we 3D printed each candidate in TPU. One by one, each gripper was tested with the same criteria to determine which of the printed grippers worked the best, and determine why the other grippers underperformed. Using this information, we refine the designs of the grippers and start the process all over again with the new designs, slowly working towards the final product and to solve the bigger problem the gripper is meant to help us overcome.

Accounting

At the beginning of the year the budget is a set amount given to our team. Our current MATE team is under an umbrella of other robotics teams which all split the cost between each of them based on needs. We are given a separate budget for our travel. Our last time competing was in 2022, due to this we went through the past three years were spent on creating a new ROV for the 2025 competition. This year was focused on improving our design and making sure our ROV is competition ready.

At the beginning of the year we create a summary sheet to allocate our budget and as we go about spending our budget we add in what that money was put towards. We then have our budget sheet in which we fill out adding in what we spend our money on in quarters. This allows us to track where and when we spend our budget.

[1]

MATE	Summary	Budgeted	Ordered Cost	Estimated Budget Remaining	Actual Cost	Actual Budget Remaining
Totals without travel and OTFRs	***Totals:***	**$4,950**	**$4,355**	**$595**	**$4,433**	**$517**
	General	$1,200	$1,120	$80		
	Mechanical	$2,800	$2,422	$378		
	Electrical	$500	$404	$96		
	Software	$450	$409	$41		
	Travel	$6,311			$4,894	$1,417

Budget Estimation and allocation

MATE	Budget	Fall	Winter	Spring	Summer	*Total*	*Average*
General	***Quarterly totals:***	$270	$0	$824	$0	$1,094	$273
	Props	$0	$0	$724	$0	*$724*	*$181*
	Small bot R&D	$270	$0	$0	$0	*$270*	*$68*
	Organization	$0	$0	$100	$0	*$100*	*$25*
Mechanical	***Quarterly totals:***	$0	$181	$2,756	$0	$2,937	$734
	Raw Stock	$0	$0	$400	$0	*$400*	*$100*
	Hardware	$0	$0	$114	$0	*$114*	*$29*
	Tools	$0	$0	$118	$0	*$118*	*$30*
	3D Printer Filament	$0	$0	$0	$0	*$0*	*$0*
	Motors	$0	$46	$1,931	$0	*$1,977*	*$494*
	Waterjet	$0	$0	$10	$0	*$10*	*$3*
	Misc. Parts	$0	$8	$0	$0	*$8*	*$2*
	Waterproofing	$0	$127	$183	$0	*$310*	*$78*
Electrical	***Quarterly totals:***	$0	$96	$445	$0	$541	$135
	Boards	$0	$46	$0	$0	*$46*	*$12*
	Components	$0	$50	$120	$0	*$170*	*$43*
	Misc. Parts	$0	$0	$325	$0	*$325*	*$81*
Software	***Quarterly totals:***	$0	$83	$325	$0	$408	$102
	Cables	$0	$83	$0	$0	*$83*	*$21*

	Boards	$0	$0	$0	$0	*$0*	*$0*
	Camera	$0	$0	$325	$0	*$325*	*$81*
	Misc. Parts	$0	$0	$0	$0	*$0*	*$0*
	Quarterly totals:	$0	$0	$650	$4,244	$4,894	$1,223
	Airfare		$0	$0	$0	*$0*	*$0*
	Hotels		$0	$0	$2,371	*$2,371*	*$2,371*
	Travel Meals		$0	$0	$200	*$200*	*$200*
	Rental Vehicles		$0	$0	$879	*$879*	*$879*
	Gas		$0	$0	$320	*$320*	*$320*
	Advisor Stipend		$0	$0	$374	*$374*	*$374*
	Other		$0	$0	$100	*$100*	*$100*
Travel	Competition Fee	$0	$0	$650	$0	*$650*	*$163*
	Quarterly totals:	$0	$6,311	$0	$0	$6,311	$1,578
Proposed OTFR			$6,311			*$6,311*	*$6,311*

What our budget was put towards this year

BoM of ROV:						
Category	**Item**	**Description**	**Type**	**Cost Per**	**Quantity**	**Total Cost**
Mechanical	BlueRobotics T200 Thruster	Drive motors to propel ROV	ReUsed	$220.00	8	$1,760.00
	Canister	Plastic tube canister	ReUsed	$200.00	1	$200.00
	Canister Lids	Flange & Bulkhead	New	$126.00	2	$252.00
	Front Camera	ExploreHD 3.0 Camera	New	$325.00	1	$325.00
	Side Camera	Secondaryanalog camera	ReUsed	$255.00	1	$255.00
	1/8" aluminum plate	Used for frame on robot	New	$140.66	1	$140.66
	Servo motor	Servo used for open/closing claw	New	$28.99	1	$28.99
	APISQUEEN 24mm 2003 mini	Motor used in turning claw	New	$21.38	1	$21.38
	General Hardware	IE. Screws, bolts, fasteners	New	$114.00	1	$114.00
	Waterproofing	Budget put towards waterproofing	New	$310.00	1	$310.00
	TOTAL:					$3,407.03
Electronics	Aurduino Mega		New	$49.65	1	$49.65
	ECE	Thruster speed controller	New	$38.00	2	$76.00
	LoRa Radio	Maduino Lora Radio	New	$18.90	2	$37.80
	Breadboard		New	$6.75	1	$6.75
	Aurduino Gyro	For balancing ROV underwater	New	$10.99	1	$10.99
	ESC	Speed controler for thrusters	New	$38.00	8	$304.00
	Step Down power module	Voltage regulator module	New	$19.99	3	$59.97
	Ethernet tether		ReUsed	$16.52	1	$16.52
	General Connectors	IE. General connectors and cables	New	$383.00	1	$383.00
	Controller	Controllers for operating robot	ReUsed	$34.99	1	$34.99
	TOTAL:					$979.67
	TOTAL COST:					$4,386.70

Our BoM of our ROV

Acknowledgements

MATE Center and Marine Technology Society – Sponsoring this year's competition
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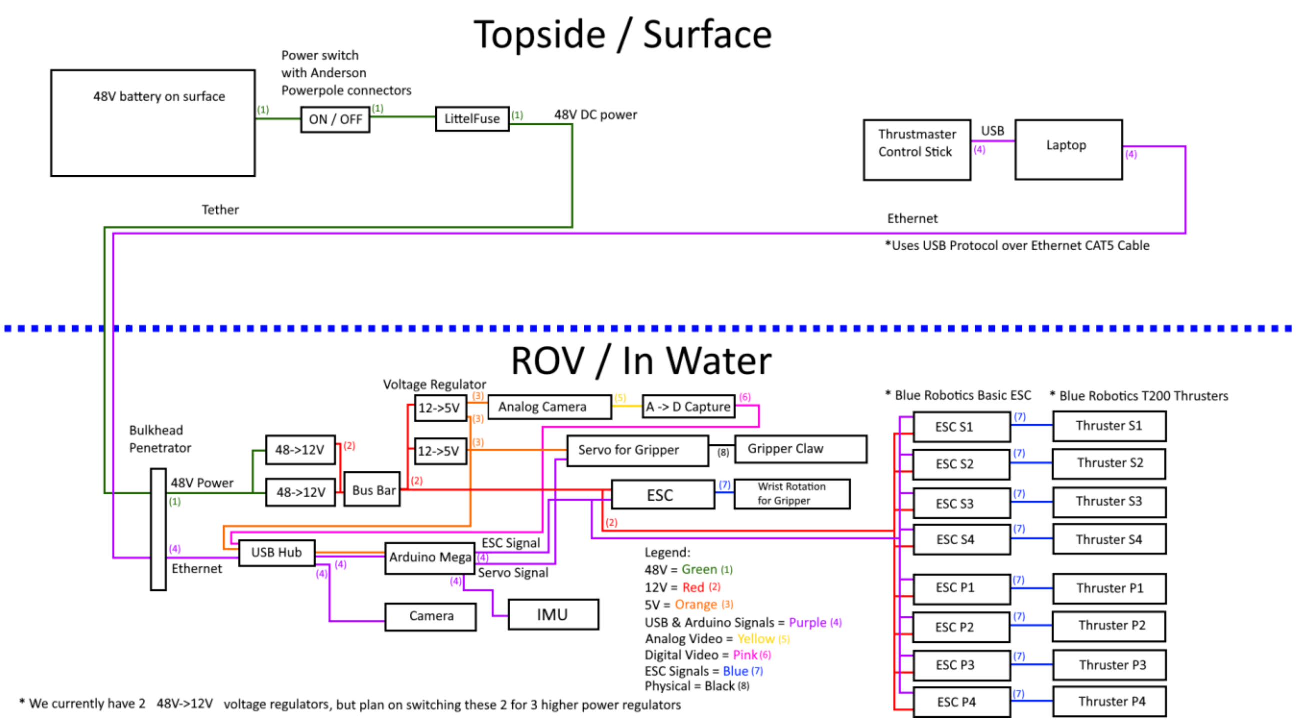
Rose-Hulman Sports & Recreation Center – Generous allotment of pool time
Rose-Hulman EIT – Providing software such as CAD software
Our families – Their continued support and encouragement
Our advisor Dr. Nathan Brooks – His wisdom and guidance

References

[1] P. M. Gerhart, A. L. Gerhart and J. I. Hochstein, Munson, Young and Okiishi's Fundamentals of Fluid Mechanics, Hoboken Nj: Wiley, 2021.

[2] Marine Advanced Technology Education, Underwater Robotics Science, Design, & Fabrication, Monterey, CA, 2010.

Appendix: System Integration Diagram (SID)



The System Integration Diagram of Scooter