PIEDMONT VIRGINIA COMMUNITY COLLEGE
CHARLOTTESVILLE, VIRGINIA, U.S.A.
MATE ROV PIONEER TECHNICAL DOCUMENTATION

Piedmont Voyager
Team Members and Roles

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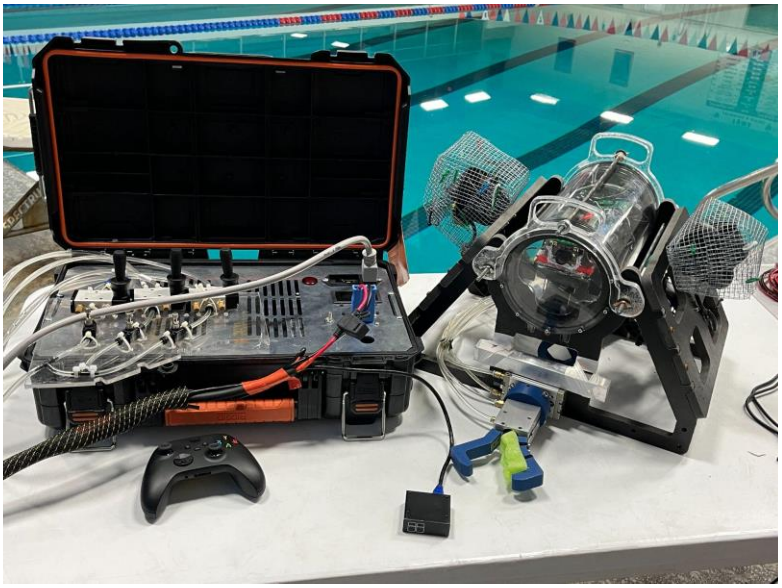

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Abstract

During the semester-long Machine Design course at PVCC, the eight members of our class were assigned a company position that was the most appropriate fit for our individual character traits and personalities. We then worked as a collective group to design and build a remotely-operated underwater vehicle in accordance with the MATE ROV's 2024, Pioneer Class Competition Manual. Once construction was completed, the vehicle would be operationally tested to ensure functional compliance to the manual, and able to complete the published tasks.

We met once every week and documented our progress after each session. Divided into two groups, one focusing on mechanical design and assembly, and the other for electrical design and integration, we were able to prioritize required tasks and evaluate total build progress. Tasks able to be completed outside of the classroom were completed over the course of the given week so that our build maintained an appropriate timeline for completion. Over the course of 16 weeks, we were able to design a stable and operational vehicle, meeting the required standards to the best of our abilities, and capable of completing as many competition tasks as possible.

Engineering Design

Engineering Design Rationale: SeaMATE ROV Project

Objective: The purpose of this engineering design rationale is to outline the key decisions, considerations, and justifications behind the design and development of the SeaMATE Remotely Operated Vehicle (ROV), ensuring clarity and transparency throughout the project lifecycle.

1. Mechanical Design:
   - Objective: The mechanical design of the ROV prioritizes durability, buoyancy, and maneuverability to withstand underwater conditions and perform precise tasks.
   - Rationale:
     - The selection of lightweight yet robust materials such as aluminum and high-density plastics ensures structural integrity while minimizing weight for buoyancy control.
     - Incorporating streamlined shapes and hydrodynamic profiles reduces drag and enhances maneuverability, allowing the ROV to navigate efficiently through water.
     - Modularity in design facilitates ease of assembly, maintenance, and potential future upgrades, enhancing versatility and scalability.
     - A fixed-mounted gripper arm minimized required moving parts, ensuring the greatest chance of success with minimal points for failure.
     - Pneumatic gripper controls provided a safer and more reliable alternative to electromechanical controls.

2. Electrical Design:
   - Objective: The electrical design focuses on reliability, efficiency, and compatibility to power and control the ROV's systems effectively.
   - Rationale:
     - Utilizing waterproof and corrosion-resistant connectors and enclosures ensures electrical components remain protected from water ingress and environmental damage.

- Implementing redundant power distribution and fail-safe mechanisms enhances system reliability and minimizes the risk of electrical failures during operation.
- Compatibility with industry-standard protocols and interfaces enables seamless integration with sensors, actuators, and control systems, ensuring interoperability and flexibility.

3. Software Development:
- Objective: The software development process aims to provide intuitive control, autonomy, and real-time data processing for efficient ROV operation.
- Rationale:
  - Developing user-friendly interfaces and control software enhances operator experience and facilitates precise maneuvering and task execution.
  - Implementing advanced algorithms for autonomy and obstacle avoidance enhances the ROV's ability to operate independently and adapt to dynamic environments.
  - Real-time data processing capabilities enable immediate feedback and decision-making, improving situational awareness and operational efficiency.

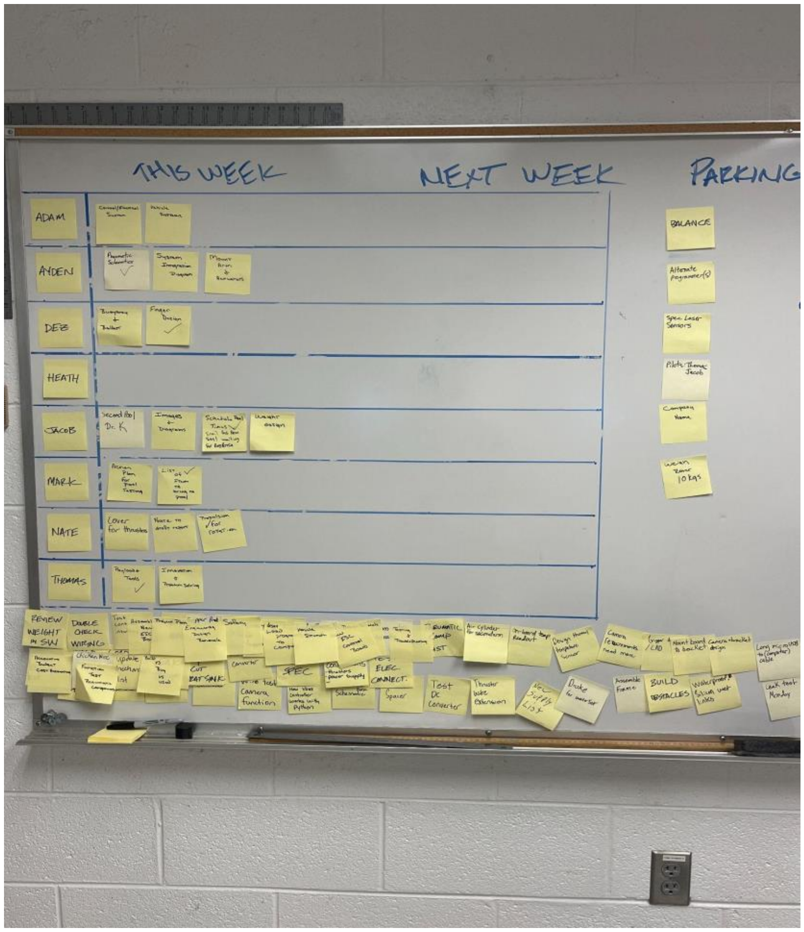
4. Integration and Testing:
- Objective: The integration and testing phase verifies the functionality, interoperability, and safety of the ROV's mechanical, electrical, and software components.
- Rationale:
  - Conducting comprehensive integration tests ensures seamless communication and operation between subsystems, identifying and resolving compatibility issues early in the development process.
  - Rigorous testing under simulated underwater conditions validates the ROV's performance, durability, and safety, ensuring reliability and readiness for real-world deployment.
  - Iterative testing and refinement based on feedback and test results optimize the ROV's functionality, addressing any identified shortcomings and enhancing overall performance.

5. Safety and Compliance:
- Objective: Safety protocols and compliance with regulations are prioritized throughout the design and development process to protect personnel and equipment during ROV operation.
- Rationale:
  - Implementing redundant safety features such as emergency stop buttons and fail-safe mechanisms mitigates the risk of accidents and ensures rapid response to unforeseen circumstances.
  - Adhering to industry standards and regulatory requirements for underwater vehicles and operations ensures compliance with best practices and legal obligations, reducing liability and enhancing trustworthiness.
  - Conducting thorough risk assessments and hazard analyses identifies and mitigates potential safety hazards, fostering a culture of safety and accountability within the project team.

This engineering design rationale provides a structured framework for understanding the decisions and considerations underlying the design and development of the SeaMATE ROV, ensuring alignment with project objectives and stakeholder requirements while promoting transparency and accountability throughout the project lifecycle.

Brainstorming

Using the competition manual as a guideline, the competition requirements were used to determine cost-effective and practical solutions to each required task. Each Thursday, our group met to develop solutions to known problems, and develop a road map to ensure the most critical components were developed. Prioritizing and delegating task completion each week ensured effective utilization of human resources.



Testing and Troubleshooting

Electrical components were assembled to the intended design specifications. Wiring was checked for continuity, and evaluated by a team member who was not directly involved in the electrical assembly process before introducing external power. Once powered, each component was dry-tested to verify functionality, per the intended design.

After confidently dry-testing each component, the main body was vacuum tested within the sealed acrylic tube. Confident that the tube was air and water-tight, the vehicle was introduced to a pool to test thruster and pneumatic controls, and correct buoyancy and balance through trial and error.

An early electrical failure occurred, which was determined to have been from an overcurrent to the thrusters resulting in thermal damage to the main control board. The control code was restructured to limit the thruster current, and additional thermal compound was used to increase the heat dissipation into the control board mounting block. Since this modification, no overheating has occurred even with more than three hours of continuous underwater operation.

Acquisition of an adequate underwater environment for testing was among one of our most complicated and time-consuming tasks. A local fitness center was one of only two, out of more than 15 initial locations that allowed us to use the facility for ROV testing. The second location that was willing to accommodate was an outdoor environment that did not open until approximately 19 April.

When the fitness center discovered broken glass in the pool, the entire location was closed to the public, leaving us searching for another space to operate. After several more failed attempts at nearby acceptable locations, the only accommodating venue was a local military academy that granted us pool access with the stipulation that we allow cadets to observe and inquire about our processes up to that point. We were more than happy to share everything that we had learned up to that point, so long as we could operate in their pool.

Vehicle Structure (Mechanical)

The final chassis design was based almost entirely on the provided SolidWorks models. However, every file with the exception of the end clamps was redrawn from scratch referencing the provided models. The redesigns ensured that the sketches and 3D modifications were labeled, fully defined, and designed as individual parts.The part models used extensive referencing to related dimensions, and use of formulas in order to ensure that any scaling or similar modifications required as few individual changes as possible to perform a complete top to bottom redesign, while maintaining symmetry and proper alignment in the final assembly.

First, a scale prototype was built using laser cut acrylic. This allowed for rapid production of consistent, high-precision parts. Each panel was modified slightly for the final form. The mounting positions for each of the four thrusters was redesigned from simple holes to curved slots. This was done with the foresight that, if any of the four thruster angles needed adjustment, new parts would not be required. The front and rear panels were modified by relocating holes for the clamping screws to better align with the provided clamp design.

Once we were collectively satisfied with the prototype design, the part files were taken to an outside company through a team contact who volunteered to cut the designs out of high-density polyethylene using a waterjet. Holes were drilled on the lateral axis of the parts that were used to fasten the panels together with screws to securely mount the six-inch acrylic tube that houses all of the electrical components. Using simple hardware to join external parts allowed for rapid interchangeability with common, inexpensive, and easily acquired parts.

The design relies solely on the four provided thrusters for underwater mobility. Two are mounted vertically on the outside of the side panels, while two are mounted horizontally on the opposite side of the panel as the vertical thrusters, closer to the midplane. Each thruster draws approximately 240 watts of power at 12 volts while operating. Each of the electronic speed controllers was programmed to operate at 50 percent to minimize thermal impact within the sealed environment.

The buoyancy system consisted of metal weights of varying mass and density secured to the front and back panels of the chassis. The design was developed using trial and error with metal blocks until a slightly negative buoyancy was achieved. After the necessary weight was determined, weights were positioned on the vehicle to ensure proper balance. The buoyancy system was chosen based on readily-available, on hand materials that could be quickly attached to the craft.

The bottom gripper was positioned along the midline of the vehicle to maintain balance. The specific design was based upon the mission requirements and evaluation of what design would perform the necessary functions to perform the respective tasks. The final design is an iteration of a straight-armed gripper that was unable to fully close around the test objects, therefore, dropping the grasped object. Using angled grippers constructed of 3D printed plastic they are able to surround the desired object to be moved while maintaining a secure closure at the ends of the gripper "fingers." The gripper length was maximized to be as low as possible on the vehicle without striking the bottom of the pool at any point in its actuation.

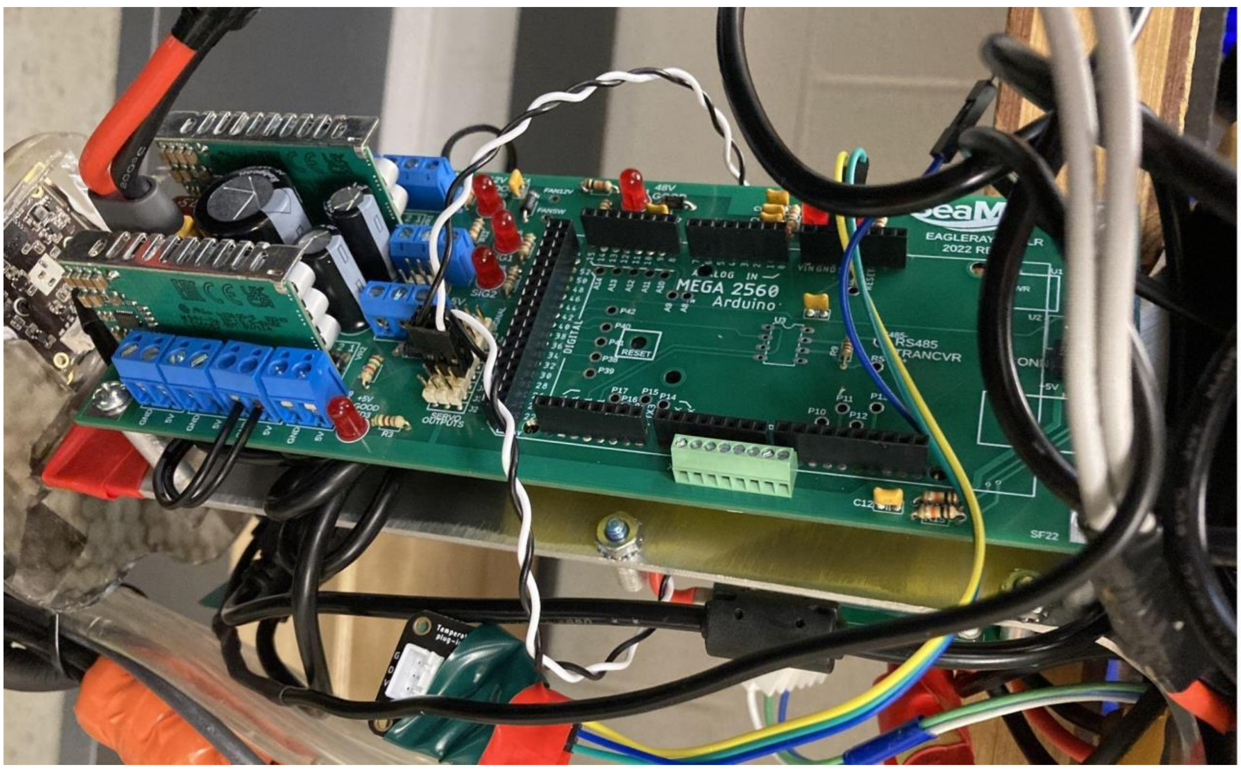
The front gripper is constructed from the same model and material as the lower gripper. It is mounted to the front panel, also along the vehicle midline for balance, but within view of the main camera. Additional pneumatic controls were integrated into the gripper arm in order to perform a rotating function solely for the task of rotating the brass valve in . task two. The entire pneumatic system operates through purchased parts consisting of three two-way valves, two aluminum manifolds, and 390 feet of tubing, all operating at 90 PSI. All components in the system are rated for 200 PSI. The total vehicle weight is 12.5 kilograms.

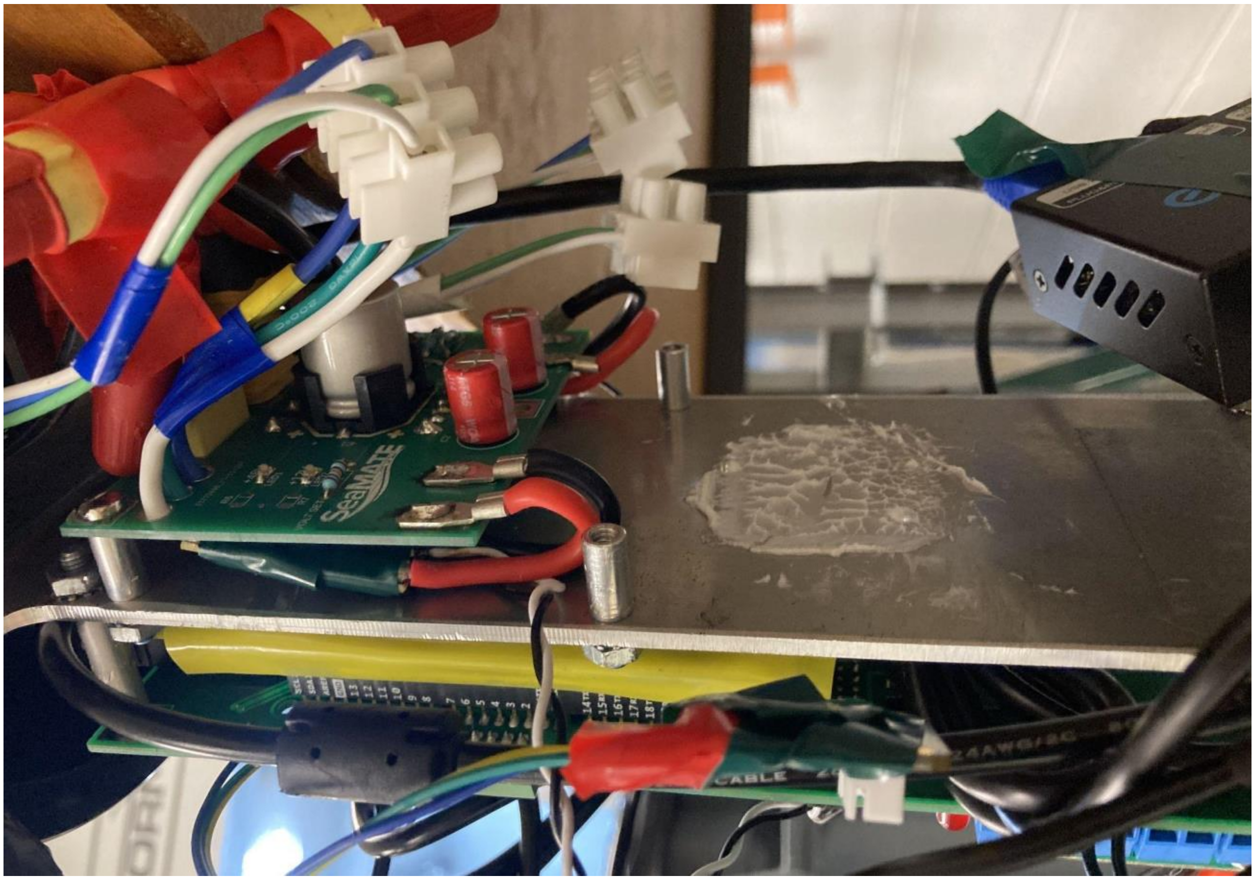
Vehicle Structure (Electrical)

Electronic Design & Cabling

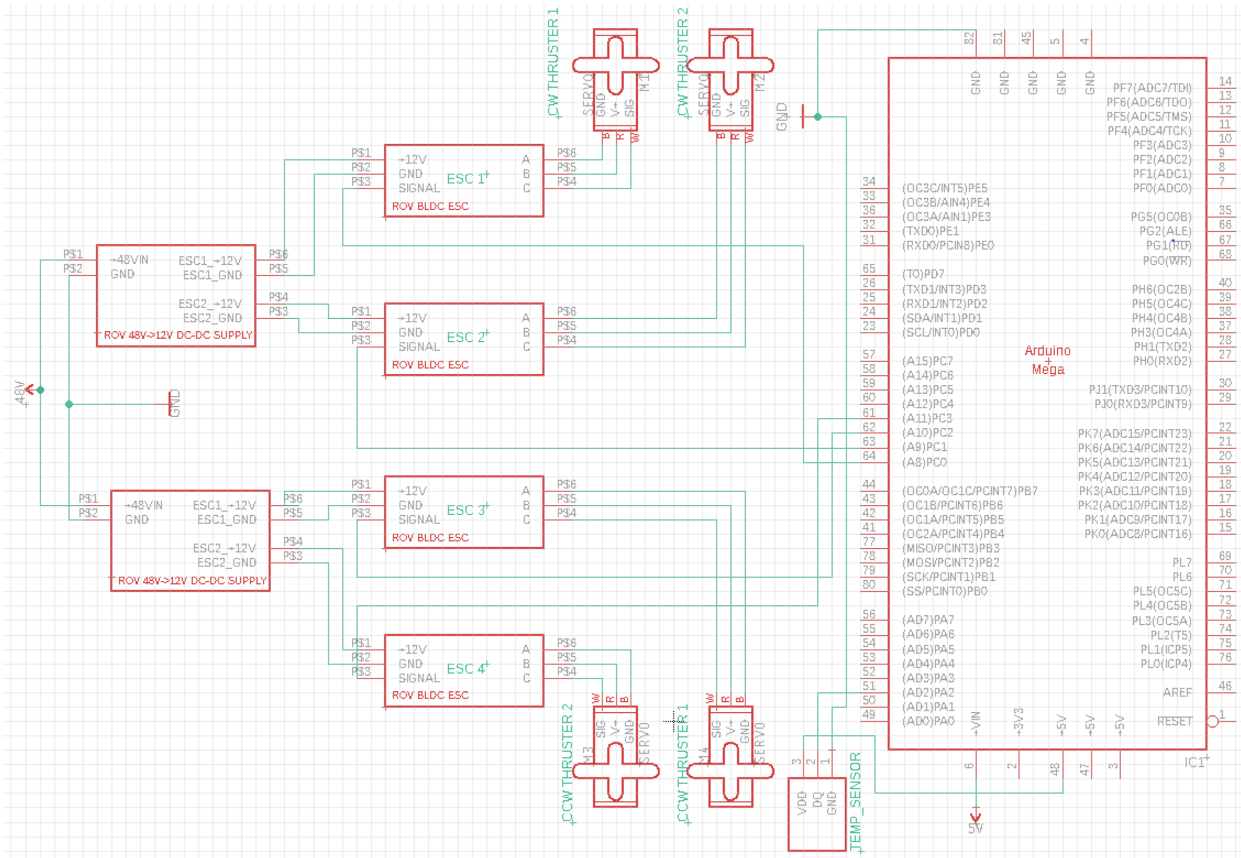
Our vehicle electrical system was designed to maintain the electrical structure provided in the ROV kit for simplicity, as this is our first round of competition for Mate ROV. Electrical control was executed via Python language coding to communicate with the Arduino microprocessor for all thruster motor function and temperature monitoring. All actuators for gripper function are controlled pneumatically. All cabling was able to be routed through the wetlinks provided into the electronics bay, and subsequently grouped together by function and interior location with electrical tape. Several of the ESC thruster wires were extended with 16 gauge cable to prevent excessive cable tension and unwanted stress on critical connections. A schematic of the internal circuitry for the Arduino control is shown below. No alterations were made to the default control board provided.

Due to the size capacity limitations of the electronics bay, one of two cameras were mounted in the end cap for underwater visibility. The other is mounted on the bottom of the frame to view the lower gripper. They are then routed to the computer via the receiver unit also supplying the Arduino communication. The transformer circuitry to supply land power (110V down to 48 V) was used from the kit materials provided for simplicity, with an ON switch and a circuit breaker switch.





EagleCAD Circuit Schematic for Arduino Control



Control System Design

Most original program code was maintained with the exception of external water temperature measurement and reporting. The thruster programming was re coded to align the axes with movement in a more intuitive way, so forward joystick movement corresponds to forward thrusting, and vertical movement on the joystick corresponds to upward/downward thrusting. The bumpers on the controller were coded to control lateral thrusters for turning capability. The Python code is provided below.

<u>Python Code for Joystick Control</u>

```
if joystick is not None:
    print(joystick.get_axis(5))
    ltrig = joystick.get_axis(4)
    rtrig = joystick.get_axis(5)
    x = joystick.get_axis(1)  # left joystick -1 is left to +1 is right (left thruster)
    y = joystick.get_axis(0)  # left joystick -1 is up +1 is down (right thruster)
    fwd = joystick.get_axis(1)
    z = joystick.get_axis(3)  # right joystick x-axis, used for vertical
    #print(x)

if abs(y) < .2:  # define a dead zone
    y = 0
if abs(x) < .2:  # define a dead zone
    x = 0
if abs(z) < .2:  # define a dead zone
    z = 0
if abs(fwd) < .2:
    fwd = 0

if onstatus.state:
    y = -y * 1.414# gives value of 1 for full thrust forward and backwards
    x = x * 1.414# gives value of 1 for full thrust forward and backwards

# rotate x and y axis of joystick 45 degrees
x_new = (x * math.cos(math.pi / -4)) - (y * math.sin(math.pi/-4))  # horizontal left
y_new = (x * math.sin(math.pi / -4)) + (y * math.cos(math.pi/-4))# horizontal right
```

```
# limits joystick values to +/- 1
if x_new > 1:
    x_new = 1.0
if y_new > 1:
    y_new = 1.0
if x_new < -1:
    x_new = -1.0
if y_new < -1:
    y_new = -1.0

ltrig = ((ltrig + 1)/2)**3
rtrig = ((rtrig + 1)/2)**3

#commands['tleft'] = -(x_new ** 3)
commands['tleft'] = -((rtrig - fwd - ltrig)/2)
#commands['tright'] = -(y_new ** 3)
commands['tright'] = -((ltrig - fwd - rtrig)/2)
commands['tup'] = -z ** 3
```

Sensors

The only sensor incorporated into the design is the exterior water temperature sensor, which was routed through one of the wetlinks and wired to the Arduino on the ROV for data reception. The DS18B20 unit was selected for its compatibility with Arduino and ease of use, requiring only a single data wire, using 5V power provided from the Arduino. The temperature reading was routed through the Json file to replace the internal temp sensor on the control board, so it could be read on the GUI.

ROV_sketch_Json_USB_Mega.ino

```
#include <ArduinoJson.h> //Load Json Library
#include<Servo.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#define ONE_WIRE_BUS 4

OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);

Servo servo_lf;
Servo servo_rt;
Servo servo_up1;
Servo servo_up2;

int val; //variable for temperature reading
int tempPin = A1;//define analog pin to read

byte servoPin_rt= 25;
byte servoPin_lf= 24;
byte servoPin_up1 = 23;
byte servoPin_up2 = 22;

void setup() {
  pinMode(LED_BUILTIN, OUTPUT);// initialize digital pin LED_BUILTIN as an output.
  digitalWrite(13,LOW);
  Serial.begin(9600);
  servo_up1.attach(servoPin_up1);
  servo_up2.attach(servoPin_up2);
  servo_lf.attach(servoPin_lf);
  servo_rt.attach(servoPin_rt);
  sensors.setWaitForConversion(false);
  sensors.begin();

  delay(7000); //delay to allow ESC to recognize the stopped signal
```

```
void loop() {
  String thruster;
  while (!Serial.available()){
   //Serial.print("No data");
   digitalWrite(13,HIGH);
   delay(100);
   digitalWrite(13,LOW);
   delay(100);
  }
  if(Serial.available()) {
    thruster=Serial.readStringUntil( '\x7D' );//Read data from Arduino until};

   StaticJsonDocument<1000> json_doc; //the StaticJsonDocument we write to
   deserializeJson(json_doc,thruster);

   //Left Thruster
   float th_left=json_doc["tleft"];
   int th_left_sig=(th_left+1)*400+1100; //map controller to servo
   servo_lf.writeMicroseconds(th_left_sig); //Send signal to ESC

   //Right Thruster
   float th_right=json_doc["tright"];
   int th_right_sig=(th_right+1)*400+1100; //map controller to servo
   servo_rt.writeMicroseconds(th_right_sig); //Send signal to ESC

   //Vertical Thruster 1
   float th_up_1 = json_doc["tup"];
   int th_up_sig_1=(th_up_1+1)*400+1100; //map controller to servo
   servo_up1.writeMicroseconds(th_up_sig_1); //Send signal to ESC

   //Vertical Thruster 2
   float th_up_2 = json_doc["tup"];
```

```
    //Vertical Thruster 2
    float th_up_2 = json_doc["tup"];
    int th_up_sig_2=(th_up_2+1)*400+1100; //map controller to servo
    servo_up2.writeMicroseconds(th_up_sig_2); //Send signal to ESC

//Read Temperature, return to surface
    val=analogRead(tempPin);//read arduino pin
    StaticJsonDocument<500> doc;//define StaticJsonDocument
    float mv = ((val/1024.0)*500);
    float cel = (mv/10);//temperature in Celsius
    sensors.requestTemperatures();
    float temp_reading = sensors.getTempCByIndex(0);
    doc["temp"]=cel;//add temp to StaticJsonDocument
    doc["volt"]=temp_reading;
    doc["sig_up_1"]=th_up_sig_1;
    doc["sig_up_2"]=th_up_sig_2;
    doc["sig_rt"]=th_right_sig;
    doc["sig_lf"]=th_left_sig;

    serializeJson(doc,Serial);//convert to Json string,sends to surface
    Serial.println();//newline
    delay(10);
  }
}
```

Tether Management Protocol

The tether system provided from the ROV kit was used to route all electrical communication and pneumatic function to the vehicle. This included ROV 48 V power, the CAT cable for the Arduino, and all pneumatic tubing. Electronics were routed through the mesh tether provided and pneumatics tubing was bunched together and zip tied to the tether. Sections of buoyant foam were added to the tether to inhibit underwater entanglement and hold all the tubing and tether together.

Vehicle Systems

For initial testing purposes, plastic acrylic was used to create a prototype of the ROV. However, the acrylic exhibited poor strength and durability capability, and also has a lower specific gravity than water which was not sub-optimal for floatation design. The acrylic was replaced with high density polyethylene (HDPE) used for the entire ROV frame, chosen specifically for its durability as well as having a similar specific gravity to that of water. However, the contribution of the electronics bay enclosure to the unit provided a positive buoyancy, so additional aluminum block weights were distributed around the frame to attain a neutral buoyancy and balance the vehicle in the water. After understanding the task requirements, we believed a neutral buoyancy would be optimal for vehicle handling, to apply as little vertical position correction as possible when completing precise tasks with the ROV. The frame material, design, and weight distributions were selected to target an overall vehicle weight that is lower than the MATE requirements.

Safety

Safety Statement:

At Piedmont Voyager, safety is our utmost priority. We are committed to ensuring the well-being of our team members, stakeholders, and the environment throughout the design, development, and operation of the Remotely Operated Vehicle (ROV). Our safety policies and procedures are designed to mitigate risks, prevent accidents, and promote a culture of safety excellence.

Safety Plan:

1. Operation Safety:
   - We conducted comprehensive risk assessments at each stage of the project to identify potential hazards and implement appropriate controls and documented risk assessment findings and communicate them to all team members to ensure awareness and compliance.

2. Personnel Safety:
   - A safety checklist was created to ensure all safety risks were identified and properly mitigated.
   - All team members were trained on safety protocols and procedures to ensure consistent adherence and preparedness for emergency situations.

3. Equipment Safety:
   - Regular inspections are conducted to maintain all ROV equipment to ensure optimal functionality and safety.

4. Task related safety:
   - Reviewed all tasks for safety compliance and performed a JSA.
   - Perform a safety brief before each task and at the end of each voyage.
   - Implement corrective and preventive actions to address safety deficiencies and enhance safety practices and procedures as they arise.

By adhering to this safety plan and statement, we are committed to creating a safe and secure environment for all Piedmont Voyager Project stakeholders, promoting the success of the project while safeguarding human life, property, and the environment.

Budget

MATE ROV Project Budget				
Available Funding				
Grant Funding				2,500.00
Funding Expenses				
Eletronic Components				80.00
Remaining Funding				2,420.00
Donated				
Electronic Componets				600.00
Pneumatic Components				300.00
Plumbing Componets				400.00
Wiring				500.00
Miscellanious Items				100.00
Pool		$225/hr	48 hr	10,800
Total Donated Material				12,700.0