2025 MATE World Championships

Technical Documentation for *Fitzgerald* ROV

Palos Verdes Institute of Technology (PVIT) Fitzgerald

Palos Verdes High School, Palos Verdes Estates, California, USA

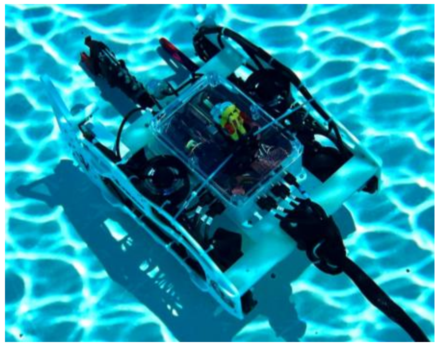

Photo 1: *Fitzgerald* ROV By: Noah Kim

2025 PVIT ROV Fitzgerald Company:

Madeline Lurie:	President, Electrical Engineer	4th year	Class of 2025
Andrew Moore:	Chief Technology Officer, Pilot	4th year	Class of 2025
Rayaan Jaffer:	Chief Executive Officer	2nd year	Class of 2026
Noah Kim:	Lead Design Engineer, Pilot	3rd year	Class of 2025
Dean Choi:	Chief Safety Officer, Lead Float Engr	2nd year	Class of 2027
Evalyn Yu:	Chief Information Officer	1st year	Class of 2028
Hadley Schmitz:	Chief Financial Officer	1st year	Class of 2027
Evie Poole:	ESG Coordinator	1st year	Class of 2026
Nathan Dorfman:	Master Scheduler, Design	1st year	Class of 2027
Kenneth Preston:	Lead Software Engineer	1st year	Class of 2028
Hailey Lee:	Regulatory Coordinator, Diver	2nd year	Class of 2027
Ananya Balaji:	Lead Mechanical Engineer, Design	1st year	Class of 2027
Daniel Chun:	Design, Mechanical Engineer	1st year	Class of 2028
Anika Savai:	Software Engineer	1st year	Class of 2028
Wesley Hsu:	Software Engineer	1st year	Class of 2028
Ayaan Chandak:	Software, Mechanical Engineer	1st year	Class of 2028

Mentors:

Lorraine Loh-Norris: Instructor
James Warren: Instructor
Fred and Julie Smalling: Mentors
Andrew Hsu: Mentor
Balaji Lakshmanan: Software Mentor

Photo 2: PVIT Fitzgerald Team
By: Julie Smalling

Abstract

The Remotely Operated Vehicle (ROV) division of the Palos Verdes Institute of Technology (PVIT) Fitzgerald company from Palos Verdes High School (PVHS) has designed and built the *Fitzgerald*, a small, lightweight, and versatile ROV to meet the challenges outlined in the 2025 Marine Advanced Technology Education's (MATE) Request for Proposals (RFP) and to address the needs of the global community. Named in honor of the Edmund Fitzgerald shipwreck in the Great Lakes, *Fitzgerald* seeks to discover, identify, and protect shipwrecks; monitor carbon dioxide levels and invasive species; increase energy efficiency and sustainability without disrupting native organisms; and deploy a float for monitoring ocean conditions.

The *Fitzgerald,* a non-corrosive, sturdy, reliable vehicle suitable for harsh environments, and *Laker*, our independent vertical profiling float, are the result of seventeen years of successful engineering in creating ROVs that have met past MATE challenges through our original designs. Custom fabricated parts, such as a manipulator, water sampler, and photosphere device, are prioritized to address our customers' specifications. Strict adherence to safety standards and commitment to human and marine life safety is upheld through waterproof electrical housing, rigorous dry and wet testing, and heavily enforced safety protocol. PVIT Fitzgerald consists of sixteen members with multiple years of expertise in ROV design, additive manufacturing, laser cutting, electronic hardware assembly, computer programming, and scientific data collection and analysis. Our well-trained pilots, desk crew, and skilled scientific support team are capable of accomplishing the tasks outlined in the RFP in order to meet the customer's needs.

Photo 3: PVIT ROV Program By: Julie Smalling

Back Row (L→R): Aiden Cruz, Nathan Dorfman, Keke Moulton, Andrew Moore, Noah Kim, Rayaan Jaffer, Ben Peters, Dean Choi, Henry Argentieri, Madeline Lurie, Ayaan Chandak, Wesley Hsu, Anika Savai

Middle Row (L→R): Genevieve Poole, Hadley Schmitz, Julia Yousif, Allison Yu, Hailey Lee, Eto Uchiyama, Ruka Ito, Ananya Balaji, Evalyn Yu, Joley Yamamoto

Front Row (L→R): Daniel Chun, Harry Forrester, Kenneth Preston, Oliver Dehn, Ishir Gaur, Will Shouse

Table of Contents

Project Management

Company Structure: PVIT Fitzgerald is a student-led engineering company with the goal of solving real-world engineering problems, becoming more sustainable, and advancing marine environment health through collaboration, innovation, and cutting-edge technology. This year, the company consisted of sixteen members, with six returning and ten new engineers. To foster mentorship while optimizing hands-on experience, members were divided into two working groups. Experienced members instructed new students weekly on skills such as soldering, using power tools, Python coding, electrical wiring, using online design software, and engineering safety. This new team structure encouraged collaboration, respectful interactions, and a supportive learning environment such that the whole company could succeed. The company is also organized into various sub-teams that work to develop different parts of the ROV. The company is also organized into sub-teams focusing on design, mechanics, software, electronics, outreach, and documentation. Each sub-team is led by a skilled member who oversees the development of their department and acts as a mentor and reference point for new members (*See* Appendix A). The CEO oversees team progress by communicating with sub-team leaders and mentors, leading biweekly meetings to discuss deadlines, and organizing community fundraising events. Important protocols such as keeping a safe working environment and staying on task are enforced and expected of each team member.

Scheduling and Planning: One of the biggest challenges this year was scheduling and planning. In order to maintain a productive work environment, PVIT Fitzgerald holds its members to high expectations and requires a large time commitment from all. As a result, communication between members was crucial in maintaining high attendance and productivity during meetings. Emails and the messaging software GroupMe were used to discuss upcoming outreach events, progress updates, and ordering parts and business-related matters. All members are encouraged to actively communicate with each other. Additionally, documenting all the company's work is vital to PVIT Fitzgerald's success. A shared Google Drive is used to store all files, including design prototypes, software, photos, budget spreadsheets, safety protocols, technical documentation, and mission related information. All company members work together to ensure files are organized into their respective folders so as to not clutter the drive.

Project management is a challenge that PVIT Fitzgerald continually faces, so the team placed special emphasis this year on establishing and adhering to a master schedule. A new role, Master Scheduler, was created to determine an approximate timeline for designing, building, and testing the ROV. We used Jira, a scheduling software, for the first time to create Gantt charts and construction checklists. The schedule lists all parts of the ROV and tasks that need to be completed. The tasks are grouped into sections including Program Management, Budget and Purchase, Design, Build, Practice Runs, Documentation, and Presentations. Each task was assigned to a specific person or sub-team with an estimated deadline and priority label. High priority tasks, which could hinder other tasks if not completed on time, were tackled first. Each member was held responsible for completing their tasks and updating the task's status as "not started", "in progress", or "done". The schedule was maintained by communicating with each sub-team leader on a weekly basis to ensure that their group was progressing according to schedule. Overall, the schedule enhanced team productivity, organization, and communication. Members were able to track the urgency and progress of each task, as well as how much of the overall ROV and MATE requirements were completed. (*See* Appendix B).

Challenges:

Training new members was a great challenge for PVIT Fitzgerald to overcome. Since newcomers outnumbered returning members by 3:2, the experienced team was responsible for teaching them crucial engineering skills, such as soldering, computer-aided design (CAD) software, and using power tools. Although some new members arrived with previous knowledge, even they had to be taught the specifics of engineering an ROV, working together on a team, and understanding how to best meet the customer's requests. However, our team was able to manage our time sufficiently to advise new members and build the Fitzgerald ROV, and strong relationships formed between older and younger students. Another challenge was meeting our final deadlines due to deviating from our project schedule. We would have benefitted from additional troubleshooting opportunities in the practice pool, thus eliminating several equipment failures during our first product demonstration which resulted in a disappointing performance. However, after this valuable learning experience, we held discussions to reevaluate design choices and scheduled times to rebuild and test in the pool for up to six hours at a time.

Design Rationale

Our company possesses a variety of resources that we use to design and develop our ROVs. PVIT Fitzgerald utilizes in-house equipment including a laser cutter, several three-dimensional (3D)-printers, soldering irons, a drill press, and belt sander to manufacture the ROV, float, and its accompanying payload tools. We prioritize manufacturing our own parts, as it allows us the flexibility to constantly evolve our designs over time with the goal of creating the best product for the customer (*See* Appendix C). Our team uses software such as Autodesk Inventor, CorelDraw, Multisim, and Adobe Illustrator, to capture concepts, create models, and test designs. Our team's effective and strategic usage of our available tools has resulted in our ROV, *Fitzgerald*.

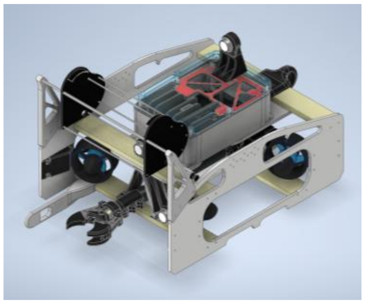

Figure 1: CAD Assembly
By: Dean Choi

Overall Vehicle Design & Systems Approach:

The primary priorities of our team this year were efficiency and simplicity in building a highly functional vehicle to completely meet the customer's needs. In developing the *Fitzgerald*'s design, our design team internalized customer task requests and placed customer convenience at the forefront. We started by assessing our own prior ROVs for their flaws and merits and drew on experience from the previous year's MATE ROV World Championships. Each member's valuable input helped us organize our ideas. By considering the positive and negative aspects of each suggestion and keeping in mind what our customer was asking for, our ROV began to take form. Our best ideas were integrated into the final design with each member's input. Our team even reached out to the Harbor Police team in the port of Los Angeles to visit and test-drive their ROV. The experience provided invaluable inspiration that fueled robust brainstorming sessions and productive discussion. A key takeaway was a design feature in the manipulator to eliminate a structural weak point (*See* Appendix D: Decision Trade-Off Table). The result is a compact and maneuverable ROV with specialized features capable of surveying shipwrecks, manipulating underwater items, and capturing live species.

Before full construction, our ROV was modelled in AutoDesk Inventor to guarantee compliance with MATE standards and for optimal performance. (*See* Figure 1). Our assembly models the ROV's major components including the "Brain Box", thrusters, side frames, cross beams, and manipulator. A substantial redesign effort was made after *Fitzgerald*'s first product demonstration, including fitting the Brain components into a different housing and moving the thrusters within the side frames. Further details can be found in our Decision Trade-Off Table (*See* Appendix D). Thanks to our streamlined, team-oriented approach, we were successfully able to create a fully functioning ROV to meet MATE standards and exceed customer expectations. Our ROV can manage power connectors, capture jellies, collect water samples, identify environments, and our float can take vertical profiles and maintain specific depths while collecting data.

Mechanical Design and Fabrication:

Our side frame design was customized to reduce water resistance by incorporating smooth, precisely rounded edges which we manufactured with our high-precision laser cutter. We selected polypropylene as the material for the construction of our side-frames because of the material's mix of strength, durability, lightweight-ness, and machinability as compared to acrylic or polyethylene (*See* Appendix D). In the interest of reducing waste and maximizing efficiency, we cut only the final version out of polypropylene. All prior prototypes were cut out of recycled cardboard (*See* Photo 4 and Figure 2). *Fitzgerald*'s six interior thrusters are oriented to provide efficient 3-axis maneuverability while optimizing power and facilitating thruster and code calculations. The thrusters are mounted inside of the housing for a more compact form factor when navigating through environmental challenges, such as avoiding contact with shipwrecks. The horizontal thrusters are mounted on angle blocks at 30-degree angles, and the vertical thrusters are mounted directly onto the side frames.

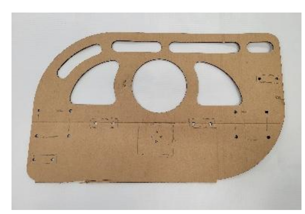

Photo 4: Cardboard Prototype
By: Allison Yu

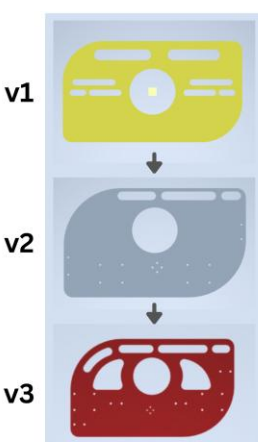

Figure 2: CAD Side Frame Iterations
By: Ananya Balaji

The onboard electronic components make up the ROV's "Brain". We use a water tight enclosure containing a RaspberryPi4, Arduino Mega, and various other electric controllers to

Photo 5: Working On Old Brain
By: Ayaan Chandak

receive and relay data between the ROV and the topside Control Box. Originally, we used an acrylic tube with endcaps, but this posed many problems due to poor access to components, which made it difficult to isolate issues and fix them within the Brain. (*See* Photo 5). Our redesigned brain features a slim, compact box. The key feature is easy access to electronics through a removable top (*See* Photo 6 and Appendix D). Our ROV receives visual data from our three mounted waterproof cameras, each having a different view. The different views of these cameras allow for a comprehensive assessment of the environment and control over the ROV. Our primary manipulator, the "claw", is mounted below the Brain. The claw is a modular component, mounted on a detachable plate for ease of servicing. All of these major components and additional payload tools were assembled according to our complete CAD assembly.

Photo 6: Easy Access to Brain Components
By: Noah Kim

Innovation in Payload Tools: The *Fitzgerald* is equipped with many innovative features inspired by the customer's requests. Our manipulator (claw), live species collector, magnetic wand, and software are all thoughtfully and creatively designed for superior functionality, as described in Table 1.

Table 1: Innovation Summary

Item	Innovative Feature	Benefit
Claw	"Rotating Wrist"	2-in-1 service. Can grip in multiple axes/direction.
Magnet	Fabrication technique embedding the magnet within the 3D print	Functionality beyond request in cleaning environment of metallics.
Code: Photosphere	Rotates one image, finds overlap between 2 images and stitches them together, and displays in Pannellum	Original code stitching two hemispherical images into a photosphere.
Code: Carp Migration	Developed five original codes tracking migration of invasive species	Made selection for the most effective for easy data input and best visual display.
Live Species Collector	Open mesh allows water to flow through while flying. Shape design captures buoyant species.	Collects live jellyfish and fish without harm.

Live Species Collector: The jellyfish collector is composed of two main parts: The "Horns" and the "Collector" (*See* Photo 7). The Horns are comprised of two 3D printed plates that provides a mounting location on the ROV for the collector's crossing threaded rod. The collector is easily attached and removed from the horns. The Collector is composed of several standoffs sandwiched between two 3D printed frames which are a unique shape creating a space to hold buoyant species secure once they are captured. Plastic open mesh is wrapped around the standoffs to provide a barrier for our specimen's containment while allowing water to flow through so that live jellyfish and fish can be captured without harm.

Photo 7: Live Species Collector
By: Noah Kim

Propulsion: We propel *Fitzgerald* using Blue Robotics T200 thrusters controlled by Blue Robotics Electronic Speed Controllers (ESCs). The team implemented a thruster configuration involving six thrusters to optimize the ROV's propulsion for the limited 12 volts (V) and 18.7 amperes (amps) power source. *Fitzgerald* has two vertical thrusters, one located on each side panel. Our four horizontal thrusters are mounted in a vectored configuration at thirty-degree angles (*See* Photo 8 and Appendix D). This mounting configuration of the thrusters helps the craft be more maneuverable and provides the speed of 3.5 thrusters in the forward and backward directions, rather than only two thrusters that a linear configuration would provide. The vertical thrusters are mounted close to the ROV's center of mass for limited sway. The lift capability of the ROV is strictly achieved from the vertical thrusters. The lift is twenty newtons (N)

Photo 8: Thruster Configuration
By: Evalyn Yu

Photo 9: Thruster with Shroud
By: Allison Yu

from each thruster for a total lift capability of forty N. To ensure optimal performance for each thruster, we ensure that they have unobstructed water flow by mounting the thrusters near cutouts within the frame. The placement of the thrusters in the frame allows for better hydrodynamics and space optimization.

Advanced programming and skilled piloting have helped us achieve effective maneuverability. Each thruster features a custom safety shroud designed to comply with the MATE specifications to prevent user injuries and protect nearby animals and plants (*See* Photo 9). As such, our design efficiently propels *Fitzgerald,* while being mindful of the environment. Our fast vehicle is well-suited to meet customer needs, allowing the customer to be able to accomplish various tasks, such as performing maintenance on offshore solar and wind farm facilities and installing sensors on a buoy, all within a fifteen-minute timeframe.

Buoyancy & Ballast: The buoyancy and ballast on our ROV is carefully designed for optimal stability and maneuverability. *Fitzgerald* is guaranteed to be stable and drive horizontally with an even weight distribution throughout the ROV. In general, stability is achieved by having buoyancy on the top, weight on the bottom, and thrusters located near the center of mass of the ROV. The two heaviest components of our ROV, the claw and the Brain, are distanced properly from each other to ensure that our ROV has an optimal balance. We mounted our somewhat buoyant Brain near the top and in the center of the ROV to keep the center of mass in the middle of the vehicle. We mounted our heavy claw on the bottom of the ROV for greater performance and stability. To further ensure balance, four of our six thrusters are located equidistantly parallel at the lower ends of our side frames. The final two thrusters, used for vertical movement, are located on the middle of each side frame to promote balance. With stability integrated into the design, no additional ballast was used, thereby keeping the vehicle weight low. We designed our buoyancy as being as close as possible to slightly positive or neutral such that our ROV will float to the surface if it suffers a catastrophic failure. Closed-cell foam from a swimmer's kickboard was custom cut, fitted, and strategically mounted to achieve ideal buoyancy.

Cameras: *Fitzgerald* is equipped with three high-definition exploreHD 3.0 Underwater ROV/Autonomous Underwater Vehicle (AUV) Universal Serial Bus (USB) Cameras from DeepWater Exploration. These cameras are waterproof, have high-definition (HD) video quality, a wide-angle view, color correction, automatic ambient lighting adjustment, and a fisheye adjustment for underwater distortion. Due to these benefits, the exploreHD cameras are essential and optimal for the ROV's operations, providing the pilot with multiple perspectives to enhance efficiency and effectiveness during tasks such as investigating shipwrecks, replacing sacrificial anodes on power stations, replacing thermistors on spotter buoys, and collecting jellies. Our cameras are strategically mounted on the ROV's frame (*See* Appendix D). The first camera is located in the front of the ROV, pointing forward. It is our main forward camera and is also used to help measure shipwrecks. The second camera is positioned forward on a side frame at a fifty-degree angle to give the pilot depth perception on the claw and what it is approaching or grasping. The third camera is raised and centered on top of our Brain Box for a forward and upward view that allows us to visualize the capture of the medusa phase jellies and various fish species. We have named this camera the "Periscope" for its high position location. This camera is also used for locating the launch port.

Photosphere: This sensor was developed to create a 360-degree photosphere to capture shipwreck environments. The photosphere device was built using two PICAM360 OSH Panoramic Cameras mounted in a waterproof enclosure. (*See* Photo 10). Each of these cameras has a fisheye lens, both of which are capable of producing a 360-degree spherical image (e.g., photograph) except for a 90-degree blind spot behind it (*See* Figure 3). We mounted two cameras back-to-back to eliminate the blind spot and stitch the two photos together. The enclosure for the photosphere device consists of two acrylic domes and custom-made mounts, and has a diameter of ten centimeters (cm). To support the photosphere device, we constructed a 9.2-meter-long USB cable connected to a dedicated laptop. To generate the photosphere image, software engineers utilized open-source libraries on Microsoft Visual Studio Code, such as cv2, tkinter,

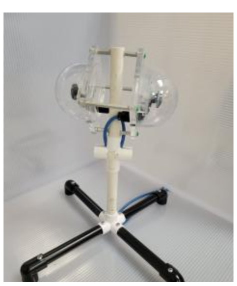

Photo 10: Photosphere
By: Andrew Moore

Figure 3: CAD View of One Camera
By: Daniel Chun

and PIL, to produce a user interface (UI) that displays the two live fisheye camera feeds and has a button to capture an image from both perspective views simultaneously. The two fisheye images captured by the photosphere device are converted into equirectangular images by finding the center of both images. Once both of the images are completely equirectangular, the code rotates the bottom fisheye image by 180 degrees and finds overlap in the images. Once a sufficient amount of overlap is found, the code stitches the two images together. Lastly, Pannellum is used to display the final result as a panorama, which can be opened in a separate browser tab and shows the surrounding environment, including shipwrecks and targets.

Manipulator: Fitzgerald's claw provides higher functionality at reduced costs by combining gripping and rotating features. The manipulator, referred to as the "claw", consists of three fingers 3D printed in two parts and is automated by a PA-06 electric waterproof linear actuator. (*See* Photo 11). A piston rod of the actuator moves to open and close the fingers, and an attached waterproof servo is used to rotate the claw. We sourced our linear actuator from Progressive Automation, our waterproof servo from Blue Trail Engineering, and custom designed our other components, such as the mount, mounting plate, fingers, and linkage pieces (*See* Appendix C). We focused on the compatibility of the claw to linear actuator, as well as the grip strength of the final design, addressing our customer's needs to accommodate all challenges specified. The claw is 3D printed out of carbon fiber nylon filament and modelled after an eagle's claw. (*See* Photo 12). The fingers of the claw open from a central point, and are interlocked when completely closed, allowing for the claw to grip various objects ranging from 1 to 10 cm wide. The fingers are attached to both a ring secured to the tip of the main linear actuator body and a plate adjusted to the center of the piston rod of the linear actuator, providing a 22N gripping force at 12V. The tips of the fingers are painted bright red to provide greater visibility and safety. The claw is mounted on a polypropylene plate, attached using two carbon fiber nylon mounts. The plate also mounts the servo and linkage pieces that attach to the end tip of the linear actuator. The entire assembly is designed to be modular, ensuring easy installation and maintenance. The waterproof servo rotates 90 degrees and is held by a mount constructed from carbon fiber nylon. The servo is attached to the actuator with several linkage pieces, allowing for the claw to hold objects vertically, horizontally, and to even rotate valves. The claw is attached to the bottom of the ROV for easy access to on items resting on the lake bed. Among other tasks, the claw is able to pick up power connectors, replace spotter buoys, and address the customer's needs.

Photo 11: Claw
By: Allison Yu

Photo 12: Claw
Finger Prototype
By: Noah Kim

Water Sampler: The water sampler is constructed using a 150 milliliter (mL) syringe and 3D printed parts (*See* Photo 13 and Appendix C). Our deck crew preloads the plunger clamp in the fingers of the claw which are designed to fit the sockets mounted to the plunger. We extract water by using the opening motion of our claw to move the plunger through the barrel. A rubber band is stretched from both ends of the sampler to keep tension and prevent the sampler from slipping out of the claw's grasp. Once we have extracted 50 mL of the sample from the target environment, flexible 3D printed stoppers deploy out. These prevent the rubber band from expelling the sample while also allowing for the ROV to safely release the sampler. Our scientific support team then determines the lake acidification through a carbon dioxide (CO_2) and pH analysis

Photo 13: Water Sampler
with Funnel Guide
By: Ananya Balaji

Float: Our vertical profiling float, *Laker*, uses a buoyancy engine constructed from a 550 mL syringe in a clear acrylic tube with a 10 cm inner diameter at a height 86 cm (See Photo 14). *Laker* is composed of internal components sealed between two custom 3D-modeled end caps with O-ring seals (*See* Photo 15). 1.5 Volt Alkaline C-batteries provide the float with independent 12V power, which is managed by waterproof penetrated switches located on the top end-cap. Safety features include a 1-amp fuse, a pressure release plug, and securely fastened batteries. The float is controlled by an Arduino Portenta Microcontroller, which controls a linear actuator stroke position and collects and relays data packets to the on-deck receiver. To determine the depth of the float, a pressure sensor is used. A closed-loop control system running on the Arduino finds and maintains the given depth of the float by adjusting the position of the linear actuator, allowing the syringe to increase or decrease the density of the float to

Photo 14: Float
By: Dean Choi

achieve target depth. Wi-Fi communication is enabled b y a waterproof antenna on the float's end-cap to allow for the sending of data packets to the router and laptop when the float surfaces. Data collected includes pressure, depth, and time, which is then graphed using a custom web application. The float runs on a 2.4 gigahertz (GHz) network to minimize interference in high-traffic frequency environments.

To achieve a fully-functioning buoyancy engine, PVIT Fitzgerald attempted to custom-model a piston which would fit precisely within the acrylic tube housing. We were unable to construct a waterproof "syringe" mechanism within our schedule timeline, and considering a mechanism with greater than 550 mL capacity was unnecessary this path was abandoned and a 550 mL syringe was purchased. All of the mounting and plating was designed in-house with AutoDesk Fusion360 software. The design process was streamlined with the use of standardized parts and fasteners, choosing M5 for the threaded rods, screws, and bolts. After dozens of revisions, the final versions were 3D-printed using a sturdy carbon-fiber nylon filament (*See* Figure 4). Our extensive water-proofing process included designs printed with a high-infill ratio and high wall count, the use of aerosolized rubber waterproofing spray, and sensitive regions being submerged in settled electronic epoxy. Rubber O-rings were used to seal connections against the acrylic tube.

Figure 4: CAD Endcap
By: Dean Choi

Tether: The tether has six wires encased in an expandable mesh sleeve and is eighteen meters in length. (*See* Photo 15). Four wires supply power and ground, while the third pair is dedicated for data transfer. Two separate power lines are optimal over a single power line since the thrusters pull enough power to interrupt the Raspberry Pi's function. Separating the thruster and control power allows the Brain and control box to receive a steady stream of power even when the thrusters are at full throttle. We chose an 8-gauge power wire for the thrusters for reduced voltage drop across the tether's eighteen meters. The smaller 14-gauge wire is more than adequate to supply the control system. The data service is a two-wire alternative for an Ethernet cable, which supports serial communication and video signals. The two wires are converted to Ethernet signals at each end of the tether through a pair of Blue Robotics Fathom-X Tether Interface boards. (*See* Appendix D.) Our tether features Anderson Power Pole Connectors on the surface and Cobalt Bulkhead Connectors on the ROV. Both ends of the tether have strain relief devices to support the tether and prevent pulling on the connectors. The tether has flotation at 1-meter intervals to achieve positive buoyancy and ensure the tether does not drag on the lake bed and harm the environment. PVIT Fitzgerald recognizes the importance of tether management and adheres to the Tether Protocol when operating the ROV (*See* Operational Checklists and Protocol).

Photo 15: Tether
By: Rayaan Jaffer

Software and Electronics

Command and Control: The "Brain" is enclosed in a waterproof acrylic box with dimensions 25cm x 17cm 10cm and houses the entirety of our electronics. A clear lid is used to observe the well-being of our circuit boards and connections, which are carefully organized within the box and held in place using a custom mounting bracket to optimize the box's tight space. Considerable effort and iterative design changes were needed to come up with the most optimal layout (*See* Photo 16).

The *Fitzgerald* uses original code written by PVIT Fitzgerald programmers to allow the best control from our pilot using a Logitech 3D Flightstick. The ROV's Brain communicates to the deck through a 2-wire Ethernet alternative. The two boards that control all three waterproof cameras and the Pololu motor controller are connected to the Raspberry Pi, and the signals for the thruster controllers (BlueRobotics ESCs), and claw servo are connected to the Arduino. *Fitzgerald*'s Brain receives its power and ground lines through separate waterproof connections, where they are then distributed to the RaspberryPi, Arduino, and a power busbar that supports the thrusters and payload tools (*See* Pictorial Block Diagram).

The control box is a Pelican case large enough to mount a monitor. It houses all the internal components on a lower

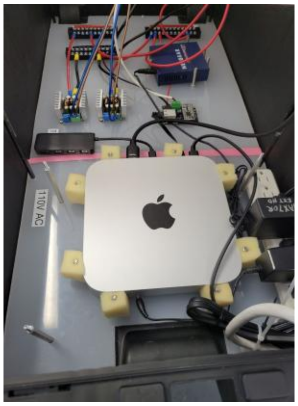

Photo 17: Control Box (Interior)
By: Andrew Moore

deck, and has a keyboard, mouse, and Volt and Amp meter on the upper deck of the control box. The lower deck holds three buses for power and ground, an Ethernet switch, Ethernet-to-two-wire converter, Mac Mini, and two current regulators. Power is taken from the main 12-volt power source into the box through Anderson Power Pole Connectors. From these connectors, a 25-amp fuse is present which leads to two switches, one to power the box, and the other to power the ROV (*See* Figure 7). The current regulator limits usage to 23 amps. Aside from the Flightstick, the setup is fully self-contained to ensure quick startup and launching of the *Fitzgerald*. A great deal of design effort went into the box layout considering access to the lower level, wire and cable management and separating alternating current (AC) and direct current (DC) power (*See* Photo 17). Strain relief is mounted on the box for the tether attachment.

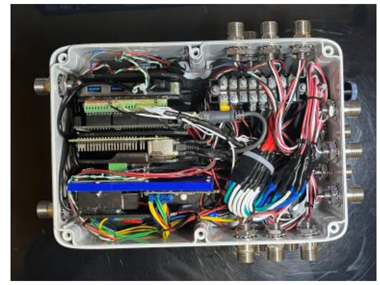

Photo 16: Brain Box
By: Noah Kim

Command, Control, and Communications (C3) Diagrams - Pictorial Block Diagram:

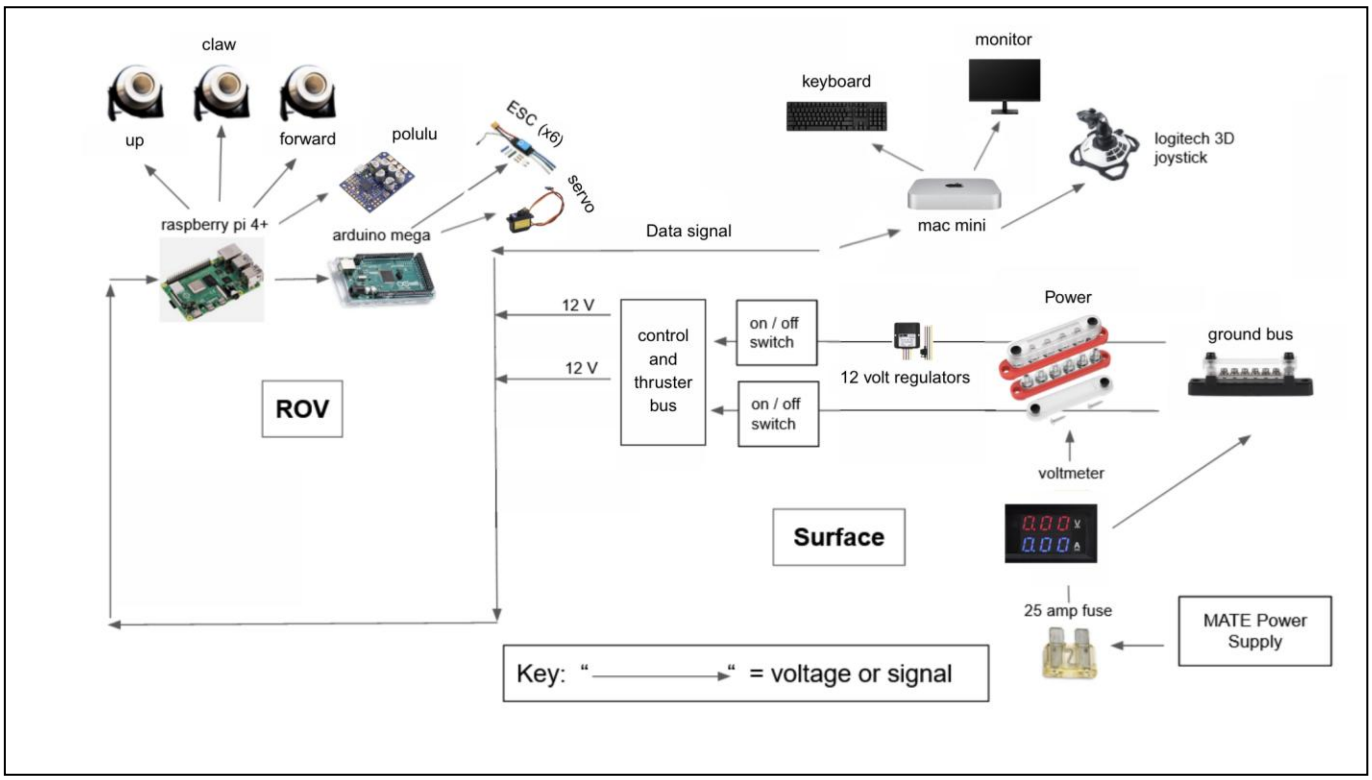

Figure 5: Pictorial Block Diagram
By: Anika Savai

Systems Integration Diagram (SID) for Float Device:

Palos Verdes High School, PVIT Fitzgerald, 2025
System Integration Diagram (SID), NRD Float:

Measured Laker Float Full Load Amps (FLA) in water = 0.526 amps
Fuse size selected based upon FLA = 1 amp
Nota bene: A 1-amp fuse is selected in compliance with MATE Specifications: ELEC_NRD-003.

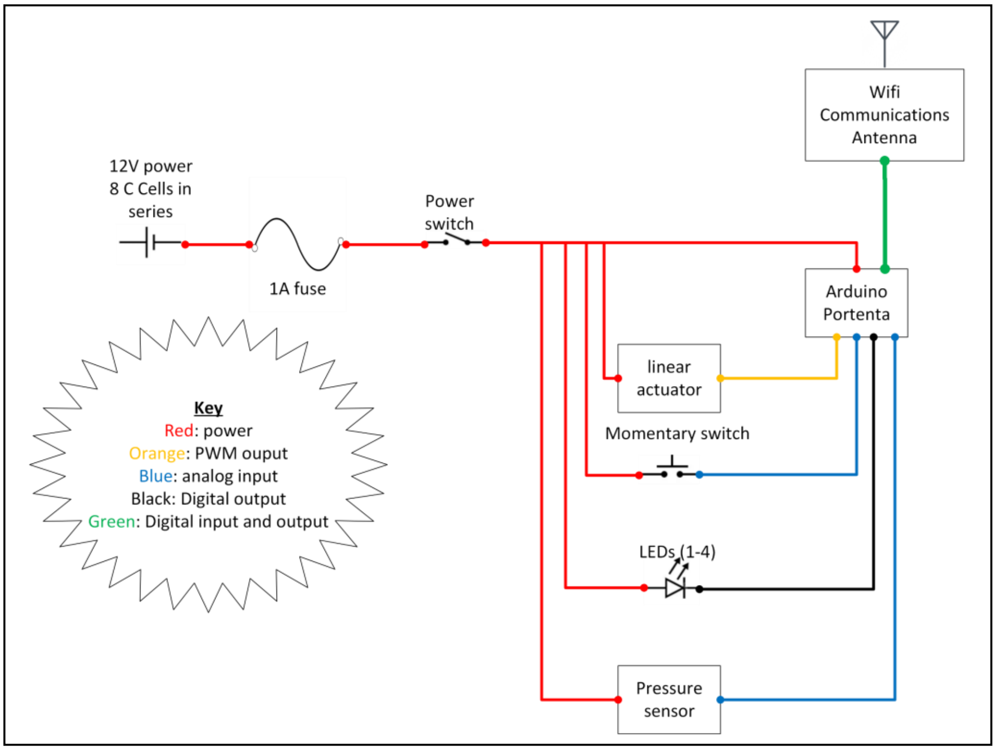

Figure 6: SID for Float
By: Wesley Hsu

Systems Integration Diagram (SID) for ROV:

Palos Verdes High School, PVIT Fitzgerald, 2025
System Integration Diagram (SID), ROV
Legend: Red (12V), Blue (5V), Green (Signal)

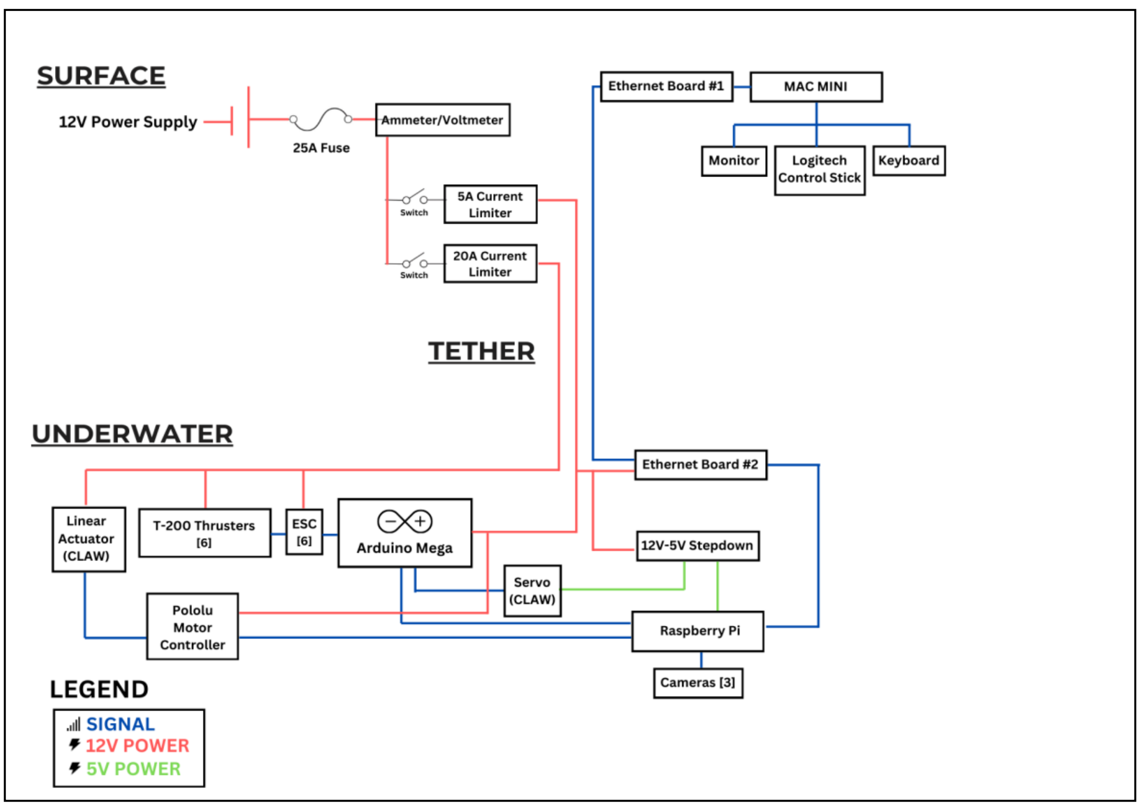

Figure 7: SID for ROV
By: Dean Choi

ROV Full Load Amps (FLA) in water = 20.7 amps
Fuse size selected based upon FLA = 25 amps
Nota bene: Our program control logic prevents simultaneous horizontal and vertical movement and prevents the thrusters from running simultaneously with the linear actuator. A 25-amp fuse is used as a safety buffer to protect wiring in the event of overcurrent.

Control Systems Design: Each component of the new software architecture has been written in the Python programming language. The Microsoft Visual Studio Code development environment was utilized in each of the operating environments used to develop *Fitzgerald*'s software. All code is currently hosted in a GitHub repository and can be accessed by each of the software engineers within the company. Each module in *Fitzgerald*'s system has been developed as a separate component using an object-oriented programming style to make it easy to understand and extend. A RESTful web services architecture, the same protocol that most online web applications run on today, handles the communication between the on-deck Commander system and the onboard ROV Brain system.

Main Command Module: The main control modules of the ROV are the Brain and Commander applications. The Brain's main control module is a Python application with an embedded web services module whose core function is to distribute the incoming and outgoing data to the various components of the ROV system and to call the necessary functions within the components that make up the ROV itself. The application works similar to a web server, where incoming requests are handled as a Hypertext Transfer Protocol (http) call (*See* Appendix D). The command system sends data to the Brain via http Application Programming Interface (API) calls and waits for a return response before relinquishing control. The architecture allows multiple clients from the command system to communicate with it simultaneously. The Commander's main control module is also a Python application, but it has a traditional main loop architecture that waits for incoming messages from the Flightstick. Based on these messages, the Commander either forwards the data to the Brain or operates the different command system modules.

Thruster Module: The thrusters are one of the most crucial parts to any ROV and must be controlled efficiently. The thruster motors are controlled from an Arduino Mega that sends Pulse Width Modulation (PWM) signals from the pins to each of the ESCs. The ArduinoMega is connected to a Raspberry Pi through a USB connection. The Raspberry Pi controls the Arduino Mega using open-source libraries. Firmata runs on the Arduino and PyFirmata runs on the Raspberry Pi. The Arduino and Raspberry Pi communicate with each other through Firmata. The Python syntax that comes from the Raspberry Pi is translated into understandable instructions for the Arduino Mega that are used to turn on and off certain pins on the Arduino. The actual architecture of the Python application in the Raspberry Pi is quite simple. One key file, br_thruster.py, controls the thrusters. The file does the first initialization of the thrusters and pins, and uses the Logitech 3D Extreme Pro Flightstick inputs to call certain routines that allow the ROV to move. There are two types of key routines within br_thruster.py, which include low-level routines and high-level routines. The low-level routines include performing the first initialization. The high-level routines are instructions given to the pins that cause the thrusters move the ROV based on the inputs from the Flightstick. The Flightstick communicates via hardware device driver open-source library known as Pygame.

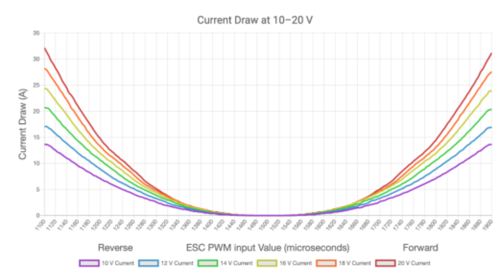

Figure 8: Thruster Power Curve By BlueRobotics.com

These high-level routines send PWM signals to each pin with a set range of signals that control the thrusters. The zero (0) value (neutral) is 1500, the maximum value for a clockwise rotation is 1900, and the maximum value for a counter clockwise rotation is 1100. These values are determined from the vendor power curves (*See* Figures 8 and 9). Each action event generated by the controller is captured and saved in the Commander deck controller or in the Brain ROV controller. The saved data is referred to as the "state" of the ROV and is used to determine what action is to be executed next.

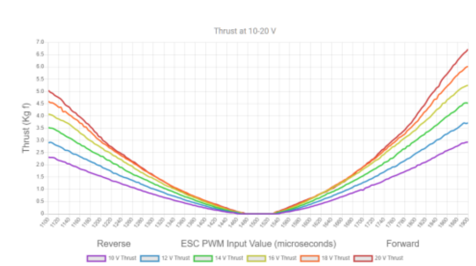

Figure 9: Thruster Amperage Curve By BlueRobotics.com

Camera Module: The cameras are crucial to the success of a pilot. The DeepWater Exploration 3.0 cameras are plugged into the USB ports of the Raspberry Pi. GStreamer, an open-source library, retrieves the streams from the Raspberry Pi and sends them through the Ethernet to a designated port on the Mac Mini. The application located on the Mac Mini takes the streams from the cameras and displays them on a web server for our pilot to view.

Build vs. Buy, New vs. Reused

PVIT's ROV teams focus on efficiency, functionality, and organization, particularly when deciding whether to build or buy parts. We prefer to make prototypes and build custom parts using available materials and tools to meet specific customer requests such as studying shipwrecks and servicing marine power sources (*See* Photo 18). We make informed choices based on trade studies (*See* Appendix D). For example, PLA has a lower infill percentage, making it an environmentally friendly, as well as cost-effective and lightweight material choice. If we choose to purchase items, we research options carefully to ensure cost-effectiveness and reliability, and build relationships with trusted suppliers such as Blue Robotics and Deep-Water Exploration. When building parts, we use design software and the appropriate tools for customization. Our Markforged Onyx 3D printer, MakerBot Replicator 3D Printer, and ULS laser cutter are heavily utilized to fabricate custom components from carbon fiber filament, polylactic acid (PLA), acrylic, and polypropylene. Refer to Appendix D for an extensive list of custom fabricated parts. High-cost, sophisticated parts such as thrusters, cameras, and bulkhead connectors are typically reused. However, after experiencing equipment failure due to reusing thrusters, servos, and cameras past their lifespans, PVIT Fitzgerald made investments in repurchasing these items.

Photo 18: Prototyping Float End Caps
By: Dean Choi

Testing and Troubleshooting

Problem Solving: When experiencing problems, team members use a data-driven process to locate the issue and determine troubleshooting methods in a collaborative environment. In manufacturing the Fitzgerald, we tested our payload tools and other devices multiple times to optimize our design and performance. When producing the software, troubleshooting and debugging is key to writing an efficient and successful program. We test the software through mock tests using light emitting diodes (LEDs) and older thrusters. For electrical work, we test every connection after we complete it to make sure that there was no bridging and that everything is properly soldered. Using a multimeter, we test the continuity of electrical systems within the Brain, tether, or control box. If continuity is intact, we test circuits to verify that they are complete. If any circuits are open, we replace the broken component and retest for a complete circuit. Once all subsystems are successfully functioning, we run dry and then wet tests on our vehicle. On the vehicle, we look for physical problems, such as interference or loose or broken parts. If no further complications arise, the *Fitzgerald* is ready to launch; otherwise, we repeat the troubleshooting process. Our rigorous manufacturing and testing practices developed over the last decade have resulted in a very reliable product.

Safety

PVIT Fitzgerald prioritizes the safety of all members above all else. We maintain this standard through consistency and teaching. As many new members joined our company this year, our team hosted orientations and regular safety check-ins to assure that all members were on the same page. We are all aligned in the common goals outlined in our Job Safety and Environmental Analysis (JSEA) documentation. (*See* Appendix F). While "Safety Officer" is a designated role within our company, we work by the motto that "Everyone is a Safety Officer." New members are paired with experienced members when handling machinery to provide insight and prevent difficulties. Weekly meetings are held to relay and reinforce topics such as hand safety, eye safety, electrical safety, and power tool safety. Everyone is informed on the proper procedure to handle and operate the ROV and other devices. Violations in procedure are corrected and marked for review at the next weekly meeting.

Additional safety measures include shrouds compliant with MATE regulation that prevent obstructions and contact with the thrusters. Safety for the environment is considered with these thruster guards and with the design of our Live Species Collector, which can capture jellyfish and fish without harming them. Warning labels are positioned around danger zones, and sharp edges are rounded. Pinch points, like the claw tips, are painted in red. Remaining sharp points are given a heat shrink to cover their edges. The electrical systems are thoroughly tested for waterproofing for both the ROV and non-ROV device. We use a combination of waterproof penetrators, waterproof coating, and pressure sealing to prevent the dangerous combination of water and electricity. On deck, there is a 25-amp fuse between the power supply and control box (Refer to DOC-001, Company Safety Review). Finally, pool safety rules include no running, active communication, and diligence to keep electrical lines away from water. All company members refer to safety checklists while operating and working around the ROV to reduce any threats to the safety of all PVIT Fitzgerald team members and any damage to the environment.

General Safety Checklist:

____Establish communication with co-workers.
____Ensure everyone has hair tied up, sleeves rolled up, and earphones/jewelry put away while using any tools.
____Ensure everyone is wearing closed-toed shoes.
____Ensure everyone is wearing safety glasses.
___ Remove loose accessories and distractions (e.g., necklaces and earphones)
____Ensure passageways are clear of objects and wires.
___ Clean workspace to avoid a disorganized environment
____Keep hazardous objects and materials away from members and the ROV when not being used.
____Keep all electronics, aside from the tether, away from water.
____Ensure all wires are carefully and effectively covered, with no exposed ends.
____Ensure the power connection and controller are connected before powering on the control box.

Operational Checklists and Protocol

Tether Protocol:

Set up:

1. Unroll the tether. Eliminate all kinks.
2. Safely plug the tether into the control box (matching all inputs).
3. Secure strain relief to the control box to prevent it from possibly becoming disconnected.
4. Prevent other employees from stepping on the tether by ensuring they are aware of its deployment
5. Connect the strain relief to the ROV.
6. Connect the tether to the ROV.

Post Run:

1. Safely unplug and disconnect the tether from the control box.
2. Safely unplug and disconnect the tether from the ROV.
3. Roll up the tether neatly on the hose reel.

On Deck Checklist:

1. Proceed with the Tether Set Up Protocol.
2. Connect the power supply and turn on to 12 V.
3. Power up the ROV.
4. Test the thrusters and the claw.
5. Test the camera views on the proper deck screens.
6. Gently place the ROV in the water.
7. Release any trapped air pockets
8. Deck crew gives the “ready” signal.
9. Pilot calls “3, 2, 1, Launch!”

Pre-Run Checklist:

1. Check the electrical power connections.
2. Dry run to check that cameras are working properly and are unobstructed.
3. Check to ensure that all waterproof seals are secure.
4. Check the thrusters to verify that they are working and are clear of obstructions.
5. Check the claw to verify that it is properly functioning.

Post-Run Checklist:

1. Turn off power in the control box.
2. Turn off the power supply.
3. Follow the Tether Disconnect Protocol.
4. Dry the ROV and set the ROV safely on the cart.
5. Clean up the work area of all materials, props, supplies, and trash.

Budget and Cost Accounting

Budget: The *Fitzgerald* Chief Financial Officer (CFO) and team leaders worked together to establish a proposed budget at the beginning of the year. The subtotal was calculated to be $8,255 (*See* Appendix E). This budget was approved by the PVIT faculty advisor.

Funding: The PVIT program and ROV company receive two-thirds of their funding from the Peninsula Education Foundation (PEF), a foundation that raises money for many different programs within the Palos Verdes Peninsula Unified School District (PVPUSD). PVHS's Booster Club and parent donations make up the remaining one-third of the funding. Additionally, PVIT Fitzgerald partnered with MOD Pizza and Chipotle to organize two restaurant fundraisers, raising $266.31 and $68.05 respectively. Both events were set up through the restaurants' websites and promoted through the PVIT ROV Instagram and the school's social media platforms. The total amount fundraised came out to $334.36.

Spending: We follow a certain procedure in order to purchase materials and parts. First, we research the internet for the items we need. We then put information on the chosen parts into a weekly form on Google Sheets. The order form then gets sent to our PVIT Director for her approval and ordering is then done by our school district purchasing department. We maintain an overall spreadsheet to record everything purchased. By utilizing this spreadsheet, we are organized in our purchasing method and can easily keep track of our parts and spending. Our total spending for this year to date is $7,554. The company used purchased, donated, and reused items to construct a capable ROV below budget (*See* Tables 2, 3, 4, and 5). This year, emphasis was placed on building an original ROV from fabricated components. Reused items were limited to shop tools, several high-cost ROV parts (particularly thrusters, cameras, and bulkhead connectors), and supplies to build props.

Table 2: Costing Summary for *Fitzgerald* (vehicle and control systems):

Costing summary (Total)		ROV System
Reused	1,999	1,999
Purchased	7,554	5,900
Donated	1,501	701
Total	11,054	$8,600

Table 3: Donated Items

Category	Item	Quantity	Unit Value ($)	Amount Discounted($)	Total Donated($)
ROV					
	Thrusters	6	235	35	210
	Pelican Case	2	400	400	800
	Pelican Control Case	1	398	398	398
	Cameras	3	311	31	93
Total					$1,501

Table 4: Reused Items

Category	Item	Quantity	Unit Value ($)	Total ($)
ROV-Control box				
	Acrylic Sheets	2	37	74
	Amp/Volt Meter	2	82	164
	Anderson Power Pole Mounters	4	20	80
	Monitor	1	120	120
	Flightstick	1	35	35
	Mac Mini	1	1,600	1,600
Total				$1,999

Table 5: Purchased Items

Category	QTY:	PART NAME or DESCRIPTION	PRICE (each)	Total ($):
ROV				$5,900
	1	Screw & Nuts Kit	10	10
	4	6-PIN male NOT HYBRID Cobalt Series Bulkhead Connector	52	208
	1	2 Pack 150ml Large Syringes	7	7
	1	14 Gauge AWG Wire - 100 Feet (Blue/Brown)	20	20
	32	Washers	1	21
	1	Heat Shrink Tubing Kit 355pcs	20	20
	14	Cobalt Series Cable, Single-ended	49	686
	4	Marine Goop 3.7oz	10	39
	1	300N Linear Servo	110	110
	1	WetLink Penetrator	12	12
	1	32GB Micro SD Card 5 Pack	26	26
	2	45KG High Torque Servo 8.4V	34	68
	4	6-PIN Cobalt Series Bulkhead Connector	52	208
	1	Powerpole Connector Contact	25	25
	6	Speed Controller	38	228
	1	Fathom-X Tether Interface Board	250	250
	6	T200 Thruster	200	1,200
	1	Screws	30	30
	2	Polyethelene	21	42
	6	Washers	1	6
	6	Hex nut 1in.	2	14
	14	Cobalt connectors (3 pin power)	46	644
	3	Raspberry Pi 5	75	225
	1	Outdoor Electrical Enclosure for Marine Applications	49	49
	1	Arduino GIGA R1 WiFi	73	73
	4	exploreHD 3.0 (400m) Underwater ROV/AUV USB General Vision Camera	420	1,680
Float				$367
	4	3 Way Tee PVC Fittings, Pipe Elbow Connector	9	38
	1	Bayco KW-110 Cord Reel, Orange	12	12
	1	Safety Utility Knife (SK-4) -	9	9
	5	Spare O-Ring Set (4″ Series)	3	15
	4	M5-0.8 x 350mm Length Fully Threaded Rod,	12	48
	1	Cable for Wireless Routers	10	10
	2	Wet-Location Toggle Switch	19	39

	2	4" (Diameter) Hose Clamp Pipe Clamp	7	14
	1	J-B Weld All-Purpose Silicone Sealant and Adhesive	7	7
	2	Fully Threaded Rod, M5-0.8mm, 1 m, Steel, Class 4.8, Zinc Plated Finish	11	21
	2	Pressure Sensor	44	88
	1	Acrylic Tube	67	67
Props				$440
	4	3 Way Tee PVC Fittings, Pipe Elbow Connector	9	38
	1	Platypus Platy 2-Liter Flexible Water Bottle	20	20
	1	PVC pipe	6	6
	1	Acrylic Pipe Rigid Round Tube Clear	17	17
	1	CALPALMY (Pack of 2) 12 x 24 Inch Clear Acrylic Sheets 1/4" Thick	39	39
	1	Sterilite 12-Pack Storage Box,	2	2
	1	TECEUM Rope – 90	8	8
	1	Cling N Seal Food Wrap	5	5
	1	Water Wiggler Toy	20	20
	1	Carbon Dioxide detector Water Test Kits	63	63
	1	VELCRO Brand Heavy Duty Tape	18	18
	2	#10 x 1/2" Pan Head Self Tapping Screw	10	20
	1	PVC fittings, various	248	248
Photosphere				$269
	3	PICAM360-CAMPT8MP	75	225
	2	JMX Acrylic/PC CCTV Replacement Clear Camera Dome	22	44
Other				$578
	1	3D Printer Filament ABS Plus	22	22
	1	6-Pack Replacement for Brother P Touch Label	18	18
	1	Tool Box	30	30
	1	EXPO Low Odor Dry Erase Markers	13	13
	1	Digital Fish Scale Hanging Scale Fishing Scale	10	10
	1	Cable Zip Ties	6	6
	1	Plastic storage box, pack of twelve	29	29
	1	MATE Regional Registration	425	425
	1	MATE Fluid Power Quiz	25	25
Total				$7,554

References

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14. BlueRobotics Depth Sensor Python Library: https://github.com/bluerobotics/ms5837-python
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16. Pannellum: https://pannellum.org/
17. Jira: https://www.atlassian.com/software/jira
18. SeaPerch Engineering Kits: https://seaperch.org/resources/build/
19. Blue Trail Engineering: https://www.bluetrailengineering.com/

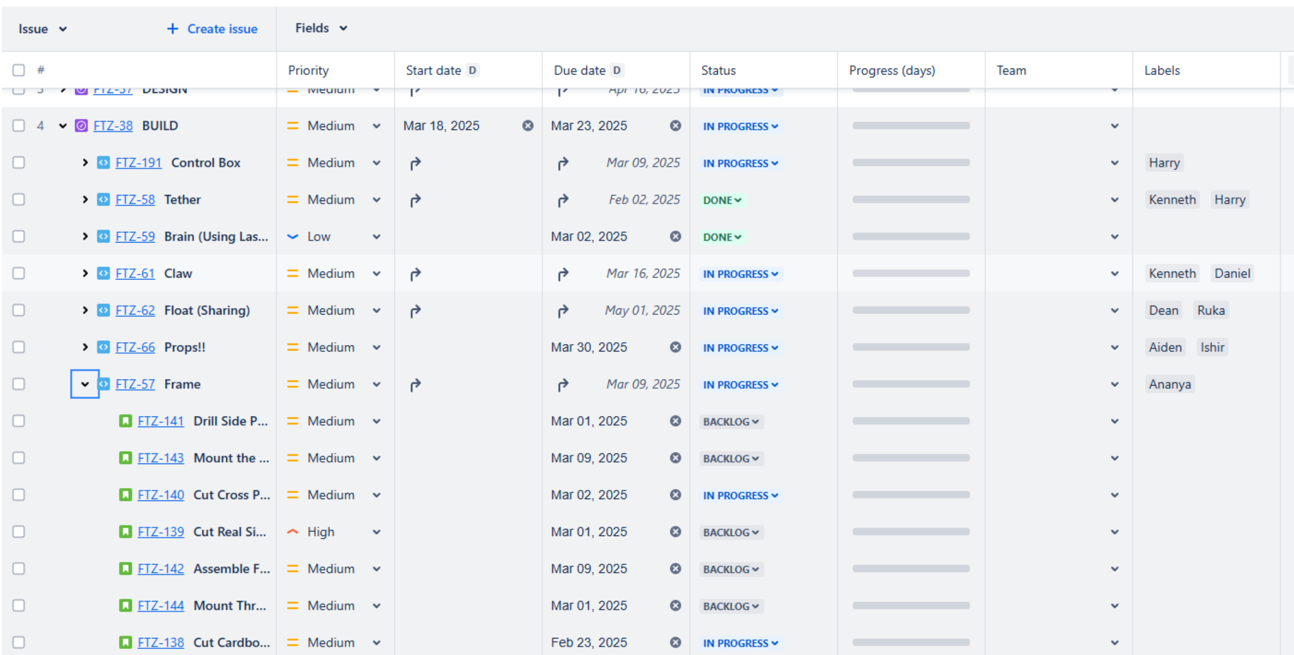
Appendix

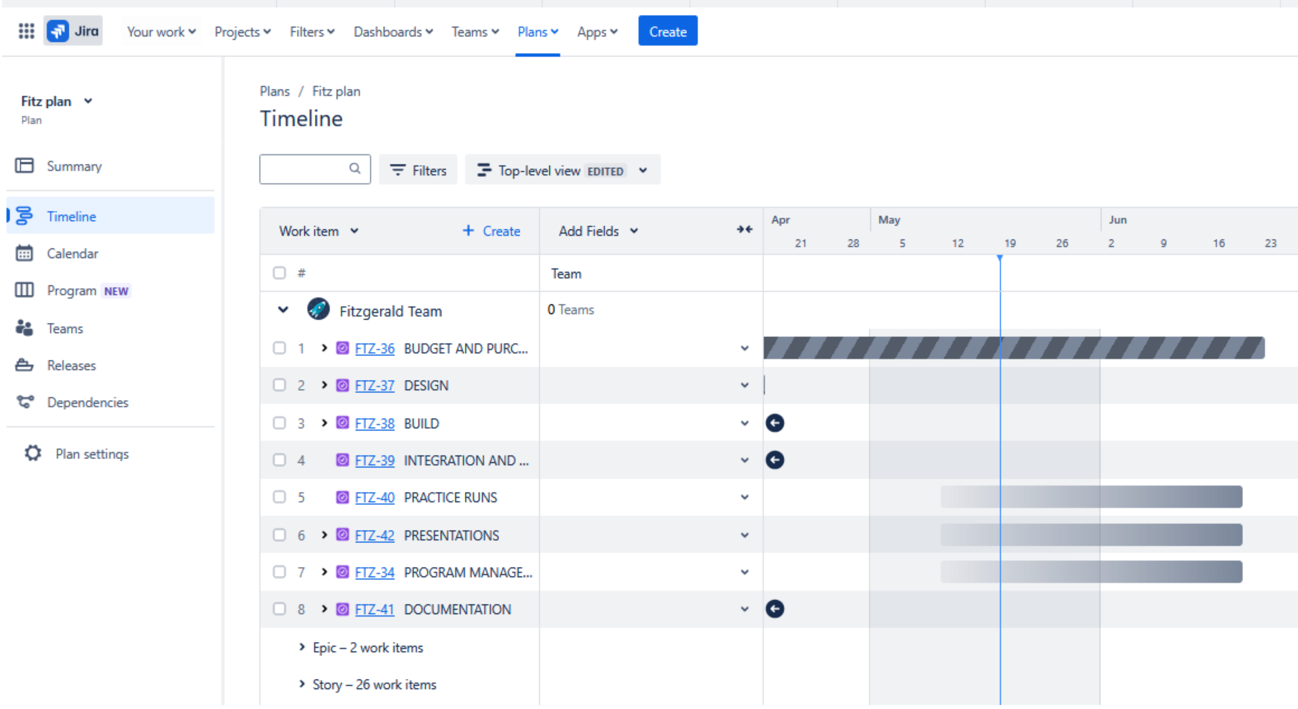
A: Sub Team Structure

* Denotes Lead

Design	Mechanical & Electronics		Software	Marketing & Information
Noah Kim*	Noah Kim*	Dean Choi*	Kenneth Preston*	Evalyn Yu*
Nathan Dorfman	Madeline Lurie	Andrew Moore	Anika Savai	Evie Poole
Ananya Balaji	Ananya Balaji	Rayaan Jaffer	Wesley Hsu	Hailey Lee
Daniel Chun	Daniel Chun		Ayaan Chandak	Nathan Dorfman
	Ayaan Chandak			Hadley Schmitz

B: Project Schedule





**Excerpt of the schedule

C: PVIT Fitzgerald Custom Fabricated Parts

LASER CUT
Frame side panels x2
Brain box mount plate
Claw mounting plate

3D PRINT, CARBON FIBER PLA
Claw actuator link
Claw actuator link axle

3D PRINT, CARBON FIBER NYLON
Frame
Thruster angle mounts x4
Front V-brace
Claw & Servo
Actuator Saddle x2
Actuator Sleeve x2
Actuator Tip
Single Finger
Double Finger

3D PRINT, PLA
Brain: Organization bracket
Claw & Servo: Servo mount
Jellyfish Collector
Horns x2
Side plate x2
Side plate pin x2
Water Sampler
Plunger front clamp
Plunger back clamp
Barrel clamp
Syringe stopper x4
Syringe funnel
Magnetic Wand (whole)
Neodymium magnet encapsulated

OTHER FABRICATION
Frame cross pieces x 4, cut & drilled
Thruster Shrouds x4, trimmed metal wire
Claw single finger brace x2, CNC Aluminum Sheet
Claw double finger brace x2, CNC aluminum sheet

D: Decision Trade-Off Table

Question	Option / Choice	+ Pros / - Cons: Trade-Offs
What housing should we use for the brain? And what type of bulkhead connectors?	Tube & Endcaps	+ Waterproof at greater depths
		+ SeaCon connectors
		-Very difficult to open and work on
	Box & Clear Lid	+ Easy to open and work on
		-Waterproof uncertainty at deep depths
		-Design and drill holes and install new Cobalt connectors
How should we angle the thrusters?	Vector Layout	+ Greater forward, back thrust and speed (3.5 thrusters equivalent)
		+ Greater horizontal direction control (spin ability)
		-Requires custom mounts, extra coding on angles
	Linear Layout	+ Simpler installation and coding
		-Slower forward and back thrust and speed (2.0 thrusters)
		-No “turn” ability
Where should we place the thrusters?	Inside Side frames	+ Thrusters protected from impacting shipwrecks and tangling in cables (solar array, spotter buoy)
		+Streamlined flying
		-Challenge to install and maintain
	Outside the	+ Easy install and maintenance access

	frames	-Susceptible to environmental hazards (cables, shipwrecks)
Claw Finger Linkage Design	Arm & Pin	-High stress, weak link, frequent breakage
	Arm in Slot	+Reduce stress to part, reliable
Water sampler	Spring actuated	+Easy to operate by claw release
		-Springs sometimes "catch" and fail
		-Springs wear out and sample size is small
	Claw actuated	+Reliable opening
		-Redesign of claw fingers
What material should we use for the side frames?	Polypropylene	+ Lightweight, durable
		+ Machinable
	Polyethylene	+ Lightweight, durable
		-Difficult to fabricate
	Acrylic	+ Appearance
		-Brittle, poor machinability
How many cameras should we use and where to locate them?	2 cameras: forward and claw	+ Less work to install, support, and expense
		-Difficult to catch species and find launch port
	3 cameras: forward, claw, and up/forward	+ Good view of all aspects for task success
		-Greater installation work, support, and costs
What kind of case should we use for the Control Box?	Small Case	+Easy to carry
		-Monitor is separate and requires longer setup time
	Large Case	+Holds mounted monitor, keyboard & mouse
		+Fast setup for use
		-Transportation cost and effort
What type of cable should we use for data transfer in the tether?	Ethernet 8-wire cable	+ Easy to use within the Brain
		-Difficult to waterproof the connection
	2-wire alternative	+ Easy to waterproof the connection
		-Must use a converter board in the Brain and control box
What software should we use to transfer data between the Mac Mini and the Brain?	HTTP connections	+ Will work if connection is temporarily broken, then reestablished
		-Slow data transfer
	Socket Connections	+ Fast data transfer
		-Will not work if connection is temporarily broken, then reestablished

E: PVIT Fitzgerald 2025 Budget

ROV Location	Item	Total Est. ($)
Regional Budget	**Subtotal ($)**	**$9,920**
Claw	Actuator, Servo, parts	795
Float	Power, housing, linear actuator, pressure sensor, antenna, electronics, hardware	1721
ROV	heatshrink, various	200
Props	PVC, Hardware, misc.	300
ROV	Blue Robotics T200 Thrusters	1,470

ROV	Computer fan covers	200
ROV	Polypropelene Sheets (1x2 ft)	330
ROV	3D Filament (Carbon Spool)	200
ROV	3D Filament (PLA Spool)	100
Expenses	Website Fees	70
MATE	Competition Registration	500
MATE	Fluid Power Quiz	50
ROV	Connectors, Cobalt	960
ROV	ESCs	210
ROV	Brain box	50
ROV	Raspberry Pi 5	180
ROV	Arduino Mega	200
ROV	Anderson Power Pole connector	20
ROV	Cameras, underwater	1,680
Tether	Wire, braided sleeve, cord spooler	111
Control Box	Anderson Power Pole Panel Mount, V/A meter, Ethernet converter boards	573
Worlds Budget	**Subtotal ($)**	**$2,180**
	Air Fare for teacher	650
	Hotel & Food for teacher	850
	Marketing Poster	100
	Transportation for equipment	500
	Brochures	30
	Trinkets	50
GRAND TOTAL		**$12,100**

F: PVIT Fitzgerald 2025 Job Safety and Environmental Analysis (JSEA) for Deck Ops/Launch and Recovery

ENTERING/EXITING THE POOL DECK AREA

TASK	HAZARD	PROTOCOL
Carrying ROV and ROV supplies	Heavy lifting	Lift the ROV with a lifting partner.
		Lift with knees.
		Have clear communication and synchronization with lifting partner.
	Crushing of fingers	Use handholds when available.
	Dropping heavy object	Keep the load close to one’s body.
		Communicate with the lifting partner.
	Awkward positioning of body	Communicate with the lifting partner.
		Keep the load close to one’s body.
	Tripping	Refrain from running and watch where you're going.

		Know the location of the tether and other tripping hazards.

SYSTEM SET UP

TASK	HAZARD	PROTOCOL
Setting up the control station	Shorting of electronics due to water	Keep the control station at least 6 feet from the pool.
		Keep wires out of damp areas.
Setting up the tether	Tripping	Inform employees of the location of the tether.
	Electrical shock	Safely plug the tether into the control box and ROV.

POWER UP CHECKS

TASK	HAZARD	PROTOCOL
Product Demo	Exposing electrical system to water	Perform the pre-run checklist prior to run.
		Ensure that electronics are waterproof.
Pre-run check	Hand injury	Test claw to ensure proper function.
		Inspect thrusters to see if they are working and clear of obstructions.
	Electrical shock	Check all electrical power connections
		Check that all waterproof seals are secure.
Troubleshooting control system	Electrical shock	Turn the power off before working on any electronics.

POOL SIDE OPERATIONS

TASK	HAZARD	PROTOCOL
ROV operation	Personal injuring.	Always wear closed-toed shoes.
	Claw and hand injury	Alert the pilot when hands are near the claw
	Tripping	Manage tether position.
		Keep passageways clear of objects.
		Always walk, never run.
		Maintain clear communication with all employees.
	Electrical shock	Follow all checklists.
		Keep the extension cord dry.
	Falling into water	Kneel on deck when placing ROV in the water
		Do not overreach into the water
	Environmental damage	Make sure no items are close to the edge of the pool

Control station operation	Shorting of electronics	Ensure that the control station always remains dry
		Follow all labels on electrical connections
Supplying props to ROV	Hands/fingers pinched	Follow the proper procedure for props
Troubleshooting control system	Electric shock	Turn the power off before working on any electronics
		Work on the dry ROV only.

SYSTEM BREAKDOWN

TASK	**HAZARD**	**PROTOCOLS**
Disconnect the power	Electric shock	Turn off all power first.
Put away the tether	Safety	Disconnect the tether from the ROV and control box.
		Work on the dry ROV only.
	Tripping	Roll up the tether carefully. Use 2 people.
Clean the area	Environmental Damage	Remove all props, materials, supplies, tools, and trash or debris from the area. Leave no trace.

G: List of Tables and Figures

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