

Technical Report

Devil Fish Robotics

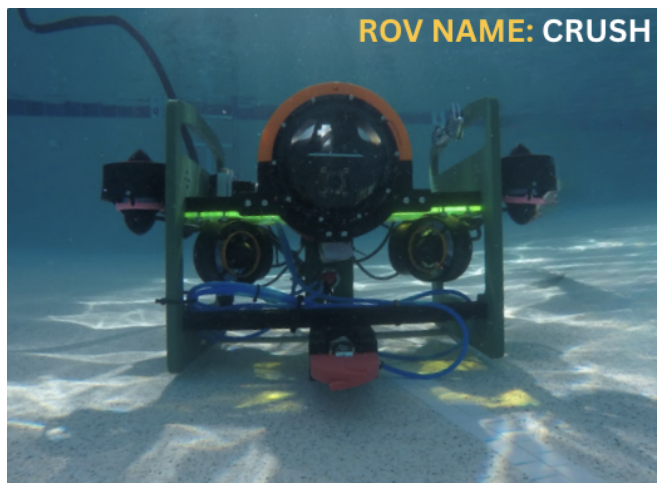
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Technical Documentation

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Abstract

Devil Fish Robotics (DFR) presents **Crush**, a remotely operated vehicle (ROV), and **Squirt**, a vertical profiler, developed for the 2026 Mate ROV Competition. Crush was inspired by the adaptability and movement of sea turtles. Both systems were created with a focus on modularity and maneuverability in underwater environments. As a first-year competition team, Devil Fish Robotics used this project to gain hands-on experience in mechanical design, manufacturing, electrical integration, waterproofing, alongside system and sub-system testing

Crush has a lightweight frame, vectored thruster configuration, waterproofed electrical systems, and modular tooling; these features are designed to improve stability and operational flexibility to accommodate mission tasks. Squirt was developed to complete a vertical profile while storing environmental data, simultaneously maintaining a compact and cost efficient design. Through an iterative series of prototyping, testing and refining, Devil Fish Robotics utilized continuous problem solving and made strategic design decisions throughout the developmental process. This technical document provides a detailed account of the team's programmatics, design approach, manufacturing process, test operations, and system integration.

Teamwork & Project Management

Company & Personnel Overview

Devil Fish Robotics is a student-led engineering organization at Arizona State University (ASU) consisting of approximately 14 active members focused on the development of underwater robotic systems for the MATE ROV Competition. Founded during the 2025-2026 academic year, the organization was created to establish an underwater robotics club at ASU after the founding members previously participated in the MATE-ROV competition under Estrella Mountain Community College.

As a first semester organization and first-year competition team, members collaborated throughout the year to plan and develop *Crush*, the team's remotely operated vehicle (ROV), and *Squirt*, the vertical profiler system. The systems were named after sea turtle characters from *Finding Nemo*, reflecting the team's inspiration from marine life and underwater exploration. Inspired by the adaptability and movement of sea turtles, the systems were designed with an emphasis on modularity and reliability in underwater environments.

Organizational structure

To improve teamwork and project organization, Devil Fish Robotics adopted an organizational structure consisting of leadership positions and specialized groups including mechanical, electrical, software, and business operations. Although members were assigned designated roles, collaboration across multiple areas was encouraged throughout the project timeline.

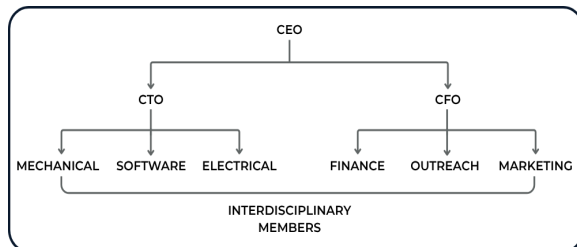


Figure 1. Devil Fish Robotics organizational Structure

Communication & Workflow

The team primarily gathered and worked from a shared workshop space – shared with other Fulton organizations., The primary location for

working was the *ASU Drone Studio*. Communication was maintained through *Discord* and weekly meetings, while additional build sessions were organized based on project need and member availability.

Resources & Protocol

Solidworks and Onshape were used for CAD modeling and manufacturing preparation while Arduino platforms were utilized for electronics integration, subsystem controls, and testing procedures. Google workspace applications including Google Docs and Google Sheets were used to support collaborative documentation, budgeting, programmatics, and project coordination between members' individual schedules working across various locations. Testing was conducted throughout the developmental process to evaluate waterproofing, electrical reliability, and overall system performance. Later stages of development incorporated in-water testing within the *ASU Sun Devil Fitness Complex* swimming pool to assess maneuverability, stability, and operational functionality in underwater environments.

Development Timeline

Development of *Crush* and *Squirt* followed a phased timeline that organized member training, development, manufacturing, testing, and technical documentation throughout the school year. Early stages focused on member onboarding, CAD development, and component research before transitioning into manufacturing, electrical integration, testing, and additional refinements.

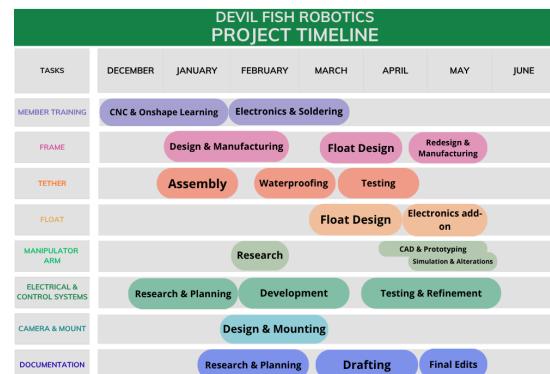


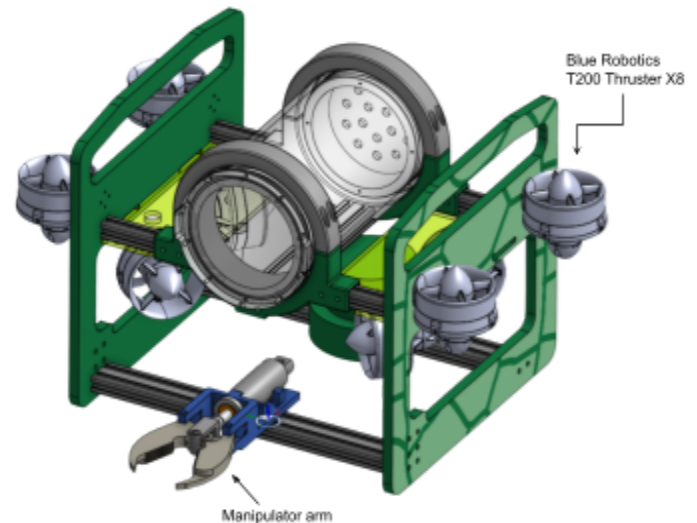
Figure 2. General Project Timeline

Design Overview

Crush is a modular remotely operated vehicle (ROV) designed to prioritize stability, maneuverability, and subsystem accessibility during underwater mission operations. The system utilizes an eight-thruster configuration with Blue Robotics T200 thrusters, an HDPE (High-Density Polyethylene) structure, integrated manipulator tooling, and a centrally mounted electronics housing to support underwater maneuvering and mission task execution.

The vehicle was designed with an emphasis on cost-effective components, modularity, and a continuous developmental process as a first-generation ROV platform for Devil Fish Robotics. Subsystems were arranged to improve overall vehicle balance, simplify maintenance procedures, and support

future subsystem modifications throughout continued development.



Design Rationale

Planning and Design Process

As a first-year competition team operating under limited financial resources during the early stages of development, many decisions were made taking into consideration the cost and quality of products.

One of the primary design considerations involved maintaining vehicle stability during underwater tasks, particularly because several competition objectives require the ROV to maintain position while subjected to water currents. As a result, the team emphasized a stable and symmetrical frame geometry, balanced component placement, and a thruster configuration capable of

Frame Design

controlled maneuvering and station keeping as is expected for this year's tasks.

The development process followed an iterative workflow involving concept development, CAD modeling, manufacturing, continuous testing, and subsystem refinement. Initial development began using the given basic frame configuration before later revisions modified the overall structure. Design revisions were continuously implemented throughout development based on manufacturing constraints, overall system performance and testing.

Figure 3. Assembly of ROV Crush

The frame of Crush was primarily constructed using HDPE. This material was selected due to its durability, corrosion resistance, relatively low weight, natural buoyancy, high tensile strength, flexibility, and overall suitability for underwater applications [1]. The material also provided a good balance between affordability and structural reliability while remaining compatible with CNC manufacturing processes available through the team's makerspace labs [8]. The frame components were designed under the constraint that it should be able to be cut on CNC machines to improve manufacturing precision and have consistent tolerances during assembly. Because the team relied on shared university makerspaces for manufacturing access, the design process considered production time and ease of fabrication throughout development. The modular frame layout also allowed components to be

repositioned or replaced more efficiently during testing and redesign stages.

Thruster Configuration

Crush utilizes an eight-thruster configuration using the Blue Robotics T200 Thruster with penetrator to improve maneuverability, stability, and overall vehicle control during underwater operations. The configuration was inspired by the vectored 6-Degrees of Freedom (DoF) frame layouts documented through ArduSub frame configurations and similar systems used in the BlueROV2 Heavy platform [9].

The thruster layout was selected primarily to support stable movement and station keeping while operating in current affected environments during competition tasks. The configuration allows controlled movement within the 6-degrees of freedom while maintaining a balanced and stable platform during operation.

Systems Approach

Devilfish Robotics utilizes a **Concurrent Engineering** framework to optimize the interplay between mechanical, electrical, and software subsystems [10]. This holistic methodology ensures that performance compromises which are inherent in multi-domain robotics, and are made strategically to maximize the vehicle's total mission envelope rather than as reactive fixes. By synchronizing the development of the Crush ROV and Squirt profiler, the team achieves a high degree of subsystem transparency and functional reliability under mission-critical conditions.

Central to our workflow is a high-fidelity **Digital Twin** system that integrates all

Attribute	Description
Strengths	Predictive Validation: Digital twin modeling significantly mitigates the risk of spatial interference and integration "surprises."
Weaknesses	Front-Loaded Latency: Extensive CAD integration requires significant initial temporal investment, delaying physical prototyping.
Opportunities	Embodied Intelligence: The digital twin serves as a baseline for future work in Causality and AI within a simulated physics environment.
Threats	Sim-to-Real Gap: Modeling discrepancies in fluid dynamics or tether drag can lead to over-optimized control laws that underperform in situ.

Table 1 : SWOT Analysis of our Systems Approach

Vehicle Structure

The structural design of Crush is designed to optimize the Strength-to-Weight Ratio while ensuring the center of gravity remains at the centroid [1]. By prioritizing a compact form factor, we ensure high maneuverability in confined environments, such as those

physical components into a unified CAD environment. This virtual model extends beyond the vehicle to include environmental task elements, allowing for the precise validation of spatial kinematics.

By maintaining a standardized mechanical and electrical footprint, we enable the parallel development of specialized manipulators, such as those required for anode replacement and environmental sampling. This modularity ensures that Crush can be rapidly reconfigured for disparate MATE RFP tasks, maintaining peak operational efficiency through optimized, mission-specific hardware swaps.

encountered in shipwreck penetration tasks, and facilitate single-operator deployment without the need for auxiliary lifting equipment. While a reduction in mass lowers the rotational inertia, increasing susceptibility to environmental disturbances, this is mitigated through a high-torque, vectored thruster configuration and active stability control laws [11]. HDPE was selected as the primary structural medium due to its near-neutral buoyancy (0.96 g/cm^3) and superior corrosion resistance compared to traditional metallic alloys [1]. This material choice allowed for a subtractive CNC manufacturing process, resulting in a rugged, open-architecture frame that facilitates rapid maintenance and heat dissipation for internal electronics. The frame geometry is specifically engineered to protect sensitive payload components while providing a rigid mounting datum for the modular tooling interfaces.

Vehicle Systems

Component Selection & Material Science

The architecture of *Crush* is a strategic hybrid of polymers and metallic alloys, selected to optimize the vehicle's displacement-to-mass ratio. The primary chassis comprises High-Density Polyethylene (HDPE) side panels, providing a low-cost, corrosion-resistant foundation with high impact damping [1]. These are bridged by 20x20 mm and 20x40 mm Aluminum extrusions, which provide the necessary longitudinal rigidity and standardized mounting datum for heavy subsystems [2]. To interface the primary electronics enclosure with this frame, we utilized custom PETG (Polyethylene Terephthalate Glycol) structural adapters, chosen for their superior layer adhesion and the chemical resistance compared to standard PLA [3].

Pressure Vessel & Thermal Management

The core electronics are housed in a custom Acrylic pressure hull, offering a clear optical path for internal status monitoring and leak detection. To mitigate the low thermal conductivity of Acrylic, the system utilizes an Aluminum backplate acting as a primary heat sink for high-draw components [6]. This passive conduction is augmented by internal forced convection, ensuring that the processing units maintain optimal operating temperatures during extended mission profiles. All external seals utilize precision-machined O-ring grooves to ensure hydrostatic integrity at competition depths.

Pneumatic Actuation System

To facilitate high-force linear motion for mission tasks, *Crush* integrates a

sophisticated pneumatic control circuit. The system utilizes a surface-supplied 75-foot, 1/4-inch OD hose regulated via a dedicated pressure gauge and relief valve for operational safety. Onboard, the flow is managed through:

Solenoid Manifold: Dual high-response solenoids directing airflow to specific actuators.

Linear Actuators: Two pneumatic cylinders providing the mechanical advantage necessary for heavy-duty manipulation.

Routing Architecture: A network of T-pipes and 1/4-inch screw-to-hose connectors ensures a leak-proof, high-flow path for rapid actuation response.

Control System & Electrical System

Electronic Architecture and Integration

The electrical backbone of *Crush* is engineered for high-fidelity telemetry and deterministic control. At the core of the navigation suite is the **Cube Pilot Orange+**, selected for its triple-redundant IMU architecture and vibration-dampened flight controller capabilities [4]. This is interfaced with a **Raspberry Pi 4+**, which functions as the primary companion computer. This dual-processor topology allows the Cube Pilot to handle low-latency real-time tasks such as sensor fusion and motor PWM generation while the Pi 4+ manages high-bandwidth data, including the processing of **three Arducam 1080p USB low-light cameras** and the network bridge to the surface station.

Sensing and Feedback Loops

To achieve the precision required for autonomous and semi-autonomous tasks, the system integrates a suite of high-precision instruments:

- **Bar30 Pressure Sensor:** Provides sub-millimeter depth resolution, enabling a stable "Depth Hold" mode critical for delicate manipulations.
- **H-Flow Sensor:** Monitors real-time current and voltage flux, allowing the

software to detect thruster cavitation or electrical anomalies before they lead to system-wide failure.

- **Optical Suite:** The triple-camera array provides a 180° field of view, significantly reducing pilot cognitive load and facilitating better spatial awareness near sensitive underwater structures.

Power Distribution and Cabling

Our power architecture is designed for safety and serviceability. The system utilizes a centralized **48V DC supply** stepped down to **12V** for thruster ESCs and **5V** for logic and sensing via high-efficiency buck converters. To ensure electrical integrity, the team standardized on **XT60 and XT30 connectors** throughout the electronics enclosure. Unlike traditional screw terminals, these keyed, high-current connectors prevent reverse-polarity events and enable the rapid removal of the electronics tray for off-board troubleshooting [7]. Wiring looms are organized using braided PET sleeving to prevent mechanical interference with internal cooling fans.

Component	Primary Role	Technical Justification
Cube Pilot Orange+	Navigation/IMU Fusion	Redundant sensors ensure stability if a single IMU fails.
Raspberry Pi 4+	Vision & Comms Hub	High-speed USB bus for multi-camera streaming.
Bar30	Depth Perception	High-accuracy I2C interface for precision station-keeping.
Arducam 1080p	Visual Telemetry	Low-light sensitivity eliminates the need for heavy auxiliary lighting.

The software architecture leverages the **BlueRobotics** ecosystem to provide an enterprise-grade control environment. The

Table 3 : Components

Control Station

The surface control station for *Crush* is designed for high-speed data throughput and low-latency pilot feedback, centering on a streamlined hardware-software interface. The physical setup consists of a high-performance laptop interfaced with an **Xbox One controller**, selected for its ergonomic precision and native driver compatibility. Communication with the ROV is established through a dedicated tethered Ethernet link, providing a robust, interference-free backbone for the transmission of telemetry and three concurrent 1080p video streams.

vehicle runs **BlueOS** on the onboard Raspberry Pi 4+, which handles camera management, system health monitoring,

and the peripheral interface. For the primary pilot interface, we utilize **QGroundControl**

(**QGC**) and **BlueRobotics Cockpit**, providing a sophisticated HUD (Heads-Up Display) that overlays real-time sensor data from the Cube Pilot Orange+ onto the live video feeds. This software stack enables precise manual maneuvering while allowing for the future integration of automated mission scripts through the **ArduSub** firmware.

By utilizing BlueOS, the ROV functions as a **DHCP server**, facilitating a "plug-and-play" network configuration. This eliminates the need for an external router and ensures that any surface station with an Ethernet port

Control System Software

The control software architecture employs a distributed, two-node topology utilizing a surface station and an onboard processing unit. A surface-deployed laptop running QGroundControl interfaces directly with a standard Xbox One controller for primary pilot input telemetry. The vehicle utilizes a **Raspberry Pi 4+** companion computer running BlueOS to manage peripheral drivers and video streaming payloads. A dedicated Ethernet tether facilitates high-bandwidth communication and IP streaming between the surface and subsurface nodes. BlueOS acts as an onboard DHCP server, establishing a zero-configuration network that eliminates external routing dependencies.

Tether Construction

The tether for *Crush* is a multi-conduit umbilical engineered to maintain high-speed data integrity, stable power delivery, and

can gain full control of the vehicle within seconds of connection. This zero-configuration protocol is critical for maintaining operational efficiency and reducing downtime during the rapid setup and teardown phases of the MATE competition.

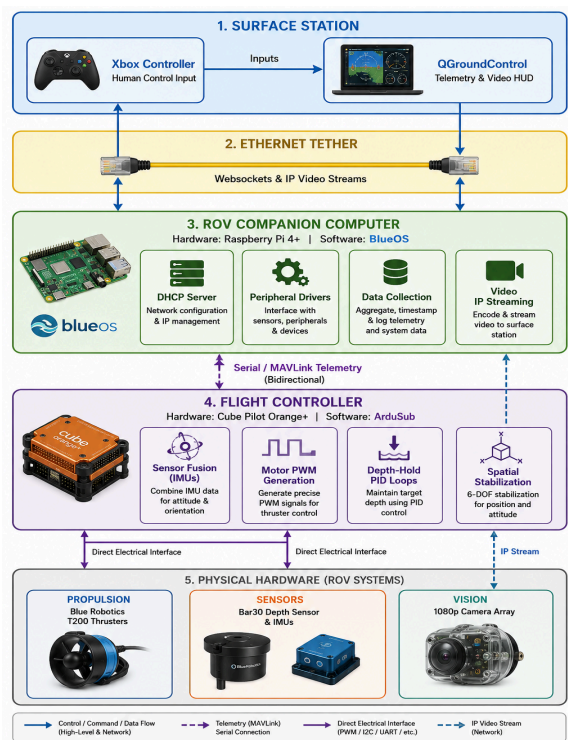
Category	Component	Technical Function
Control Software	BlueOS / Cockpit	Manages onboard systems, video streaming, and peripheral drivers.
Ground Station	QGroundControl	Primary telemetry visualization and vehicle configuration interface.
Pilot Input	Xbox One Controller	Precision joystick input for 6-DOF vectored thruster control.
Firmware	ArduSub	Executes complex PID control loops and stabilization algorithms.

Table 4 : Control Station

Subsurface control relies on ArduSub firmware executing on a **Cube Pilot Orange+ flight controller**. The firmware governs deterministic, low-latency proportional-integral-derivative (PID) loops essential for spatial stabilization and station-keeping. Sensor fusion algorithms integrate data from triple-redundant IMUs and a Bar30 depth sensor to enable automated depth-hold capabilities. This dual-processor architecture successfully isolates high-bandwidth video processing on the Pi 4+ from critical motor PWM generation on the Cube Pilot. This segregation inherently introduces inter-processor latency and increases overall system complexity compared to monolithic architecture

pneumatic pressure over a **75-meter span**. Constructed utilizing the specialized **MATE Tether Kit**, the assembly focuses on maximizing tensile durability while

minimizing power drop. To facilitate



assembly and ensure the conduits could move freely within the protective outer layer, a lubrication protocol was implemented by utilizing a combination of a surfactant and water to pull the internal lines through the expanded sleeving without compromising the jackets of the sensitive ethernet or pneumatic lines.

Internal Architecture and Conduits

The umbilical core is comprised of four primary functional elements, bundled to ensure a uniform cross-section and predictable underwater behavior:

Data & Power: Communication is established via an underground-grade aerial Ethernet cable for high-bandwidth telemetry, paired with **12-gauge zip power lines** to handle the high current demands of the eight-thruster array.

Pneumatics: Two **1/4-inch pneumatic tubes** are integrated to supply the vehicle's

linear actuators, requiring the tether to maintain structural integrity under internal pressure.

Mechanical Strength: A **high-density foam rope** serves as the central strength member and buoyancy compensator, providing the necessary tensile reinforcement to protect the electrical conductors from strain during deployment or recovery.

Armor: The entire bundle is encased in an **expanded polyester sleeving**, providing a low-friction, abrasion-resistant exterior that protects the internal conduits from environmental wear.

Performance Metrics

At 75 meters, managing **voltage drop** ($V_{drop} = I \times R$) is a critical engineering constraint. The selection of 12-gauge conductors was a strategic decision to minimize resistive losses over the extended run, ensuring the onboard converters receive the requisite voltage to maintain logic stability and thruster torque. The inclusion of the foam rope ensures the tether remains neutrally buoyant, preventing it from entangling with submerged task elements or dragging along the pool floor.

Tether Management Protocol

Operational Guidelines for Umbilical Integrity

Designated Personnel: A "Tether Tender" is assigned to every launch to manage slack and monitor for entanglement.

Deck Preparation: The tether must be uncoiled in a **figure-eight pattern** to prevent torsional kinking

and ensure smooth payout.

Connection Sequence: Secure physical strain relief at the surface station first, followed by the high-voltage power lines, and finally the Ethernet data link.

Verification: Conduct a physical inspection of the ROV-side penetrators and strain relief grips prior to submersion.

Dynamic Slack Management: The tender must provide enough slack to allow the vehicle to reach mission depth while preventing excess line from floating into the thruster intake.

Pilot Coordination: The pilot must minimize consecutive 360° rotations to prevent internal conductor twisting (torsion).

Physical Protection: Strict "No-Step" zones are enforced around the tether to prevent crushing the pneumatic tubes or Ethernet shielding.

Post-Mission Recovery: After disconnecting power, the tether is rinsed in freshwater (if saltwater deployed) and coiled for storage.

Propulsion (thrusters)

The propulsion system of Crush utilizes eight **Blue Robotics T200 Thrusters**

Payload and Tools

-Camera: Arducam 1080P

-Sensors: Bar30Depth & IMUs

Crush utilizes a dual-camera vision system using Arducam 1080p low-light USB cameras to improve underwater navigation

selected for their reliability, compact form factor, and strong thrust output while remaining reasonably affordable for a first-generation competition vehicle. The T200 thrusters operate within a 7-20 V range and can produce up to 5.1 kg-f of forward thrust at 12V, providing enough maneuverability and the stability needed for the underwater operation.

Buoyancy and Ballast

Maintaining stable buoyancy and vehicle balance was a major design consideration throughout the development of Crush. Because several competition tasks require stable positioning and controlled maneuverability in current affected environments, the vehicle was designed to maintain near-neutral buoyancy while supporting reliable underwater operation. The HDPE frame structure contributed positively to the buoyancy characteristics of the vehicle due to its relatively low density and light weight properties [1].

Additional buoyancy materials and ballast weights will be refined further to improve vehicle balance, reduce unnecessary pitch and roll, and optimize station-keeping performance during competition tasks. The modular frame layout also allows ballast and subsystems (i.e. camera and claw) placement to be adjusted more efficiently throughout redesign and testing stages.

and task execution. The cameras feature **Sony IMX291 2MP CMOS sensors** with 1080p video capability, wide dynamic range (WDR), and low-lighting imaging performance capable of operating in illumination levels as low as 0.001 lux (perfect to simulate conditions in sea). The

system also utilizes a 160deg fisheye lens configuration to improve field of view and reduce visual blind spots during underwater operations.

To improve vehicle stability and operational awareness, Crush also integrates onboard sensing systems including the **Blue Robotics Bar30 Pressure Sensor depth sensor** and inertial measurement units (IMUs). The Bar30 sensor is capable of measuring pressures up to 30 bar, corresponding to approximately 300 meters of water depth, while providing a depth resolution of approximately 2mm in

freshwater. The sensor operates on 3.3V logic with power input up to 5.5 V, allowing compatibility with the vehicle's onboard control systems. The integrated pressure and temperature sensing capabilities provide real-time depth feedback to assist with positioning, depth monitoring, and station keeping. IMUs are utilized to monitor vehicle orientation and angular motion, allowing the control system to evaluate pitch, roll, and yaw behavior. Sensor integration and placement are components constantly tested and iterated for improved performance throughout the build process

Build vs. Buy Strategy

As Devil Fish Robotics was established as a first-year competition team, the baseline engineering strategy fundamentally favored purchasing new, commercial-off-the-shelf (COTS) electronic components while emphasizing the custom, in-house fabrication of all mechanical systems. Lacking a legacy inventory of reusable parts, the company systematically justified every procurement decision based on a strict matrix of cost, reliability, and manufacturing capacity. This approach minimized early developmental risk in complex electronic domains while maximizing our team's exposure to mechanical design and CNC manufacturing.

Newly Purchased Commercial Systems

The decision to buy new commercial components was driven by the need for guaranteed operational reliability and compliance with strict MATE safety standards in high-risk domains, specifically power regulation, control logic, and propulsion

System	Justification for Purchasing New
Blue Robotics T200 Thrusters	Meets requirements: Reliable 5.1 kg-f thrust, integrated penetrators, and IP-20 compliant construction necessary for safe 6-DoF maneuverability.
Cube Pilot Orange+	Meets requirements: Triple-redundant IMU and vibration-dampened flight controller capabilities ensure deterministic stabilization and low-latency control logic.
Pneumatic Solenoid Manifolds	Meets requirements: Guarantees leak-proof, high-response airflow to actuators, preventing catastrophic subsea pressure failures.
75-foot Tether Assembly	Meets requirements: Commercial-grade aerial Ethernet and 12AWG power lines ensure high-bandwidth data integrity and stable power delivery over distance.
Bar30 Pressure Sensor	Meets requirements: Provides the precise sub-millimeter depth resolution necessary for automated depth-hold capabilities and hull integrity monitoring.

Table 5 : Justification for Purchasing new

New Custom-Built Systems

The decision to build custom components in-house was driven by the necessity for tight system integration, budget optimization, and fulfilling the unique geometric constraints required by the 2026 MATE RFP tasks.

System	Justification for Building Custom
HDPE Frame Structure	Meets requirements: CNC-machined in-house to provide a rugged, corrosion-resistant chassis with near-neutral buoyancy, significantly reducing costs compared to commercial metal frames.
Pneumatic Manipulator Jaws	Meets requirements: Custom-designed mechanical end-effectors specifically engineered to handle high-force container operations and delicate coral sampling.
Acrylic Pressure Hull	Meets requirements: Custom-sized to house our specific electronics footprint while utilizing an aluminum backplate for necessary internal thermal management.
Thruster Shrouds & Caging	Meets requirements: Custom-designed and fabricated to protect personnel and prevent entanglement, explicitly adhering to the 12.5 mm IP-20 mesh safety standard.
Squirt Vertical Profiler	Meets requirements: Built from scratch to satisfy Task 4 specifications while maintaining a compact, cost-efficient form factor tailored to our specific environmental data collection loop.

Table 6 : Justification for Custom Building

Testing & Troubleshooting

During testing of the DFR ROV, there were two major issues: pneumatic system leaks, and enclosure leaks. The first time DFR tested the pneumatic system, the team heard a leak in the pneumatic system, so the team sprayed soapy water over the system to visually inspect where the leaks were coming from. The team found that the leaks came from the threads and the connection points to the pneumatic tube and the other pneumatic components. So, the team unscrewed and inspected the joints and applied new plumbers tape. After testing and checking for leaks, the pneumatic system was completely sealed. However, while testing the ROV in the water and switching the solenoid positions, there turned out to be more leaks but these were minor and did not impair testing or system damage and were fixed after testing was done.

During the first in-water testing of the ROV, after many hours of piloting, the team noticed that there was water inside the bottom of the enclosure. Before throwing the ROV in the water, the team ran a leak test of the enclosure by vacuum pumping it and visually inspecting if the air leaks out, which failed the test (specifics on the leak test in Appendix B, E). So the team vacuum pumped the enclosure again and sprayed soapy water to see where the leak was at. However, there was no visual inspection on the enclosure. So the team hypothesized that it was the Ethernet cable that wasn't completely waterproofed since the cable wasn't waterproofed. However, the ROV tests dismantling the ROV enclosure and testing each penetrator plug, the team found that the leak came from the penetrator plug for the pneumatic solenoids electric wires. So after adding additional epoxy to the plug, the enclosure passed the leak test and was completely waterproof.

Surface Station



In-water (ROV)

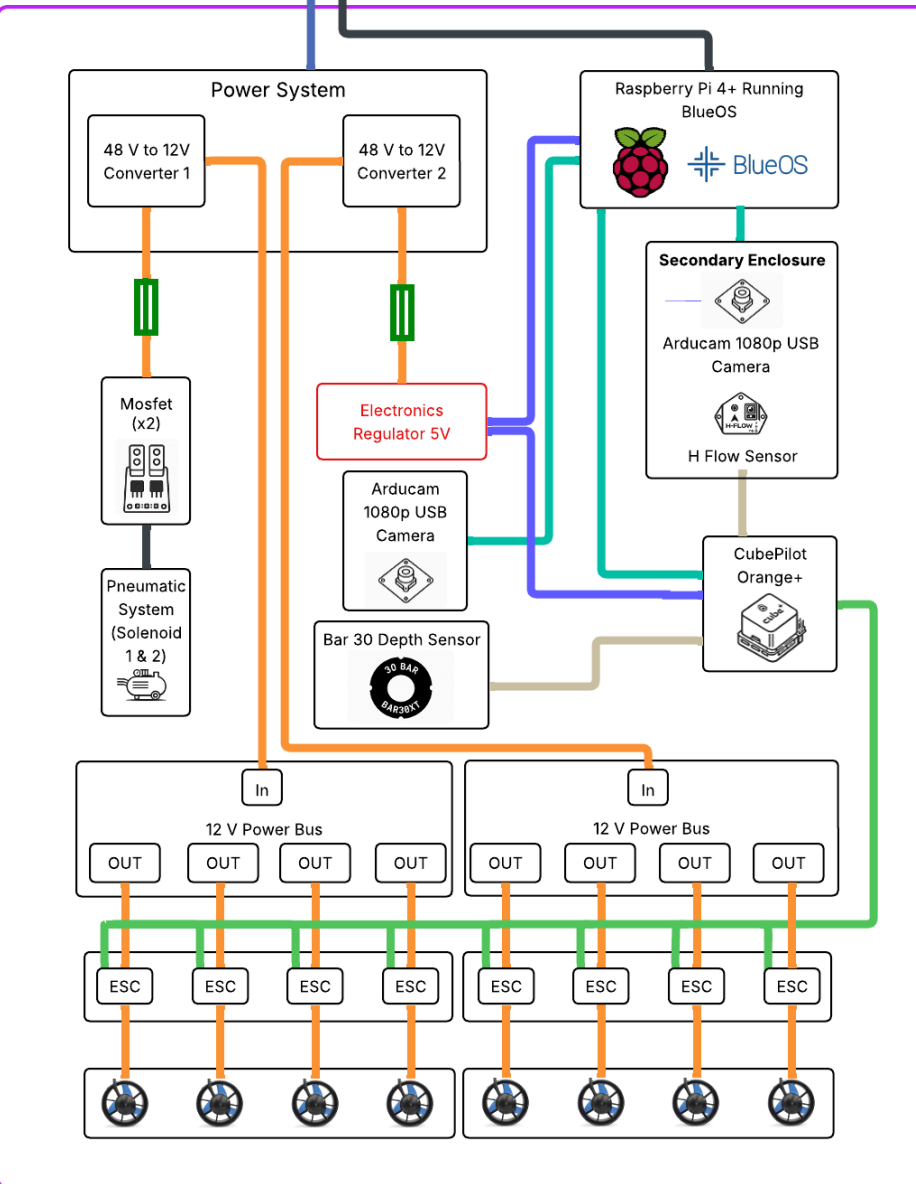


Diagram key

- Power and Ground (48 V)
- Power and Ground (12 V)
- Power and Ground (5 V)
- PWM
- Ethernet
- USB & Serial
- I2C

Measured Full Load Amps (FLA): 21.9

Fuse Chosen : 25A Fuse

Safety

Company Safety Philosophy

Safety was an important consideration throughout the development, manufacturing, and testing of Crush and Squirt. Team members were required to follow standard laboratory and workshop safety procedures during manufacturing, assembly, soldering, and testing operations. Safety equipment including safety glasses, gloves, masks, ear plugs, long pants, and closed toed shoes were utilized when operating various machinery or power tools. Members using CNC machinery drills, soldering equipment, or other fabrication tools were guided by experienced members or makerspace personnel before operating equipment independently.

Because the ROV operates in underwater environments, waterproofing and electrical protection were major design priorities throughout development. Electrical connections were continuously inspected and tested during subsystem integration and testing to reduce the risk of water intrusion and electrical failure during operation.

Protective housing, cable management systems, and strain relief methods were incorporated throughout the vehicle to reduce stress on electrical wiring and tether connections. The team also performed waterproofing checks and controlled in-water testing procedures before extended underwater operation.

Lab Safety Protocols

To be able to have access to our lab and makerspaces, each member has to undergo online safety training to understand and know the proper precautions and procedures to maintain a safe environment. All members of the team abided by ASU Lab Safety protocols under EHS [5].

Safety Features

The ROV and Vertical Profile were designed with the constraints that the user should be able to safely operate both Crush and Squirt.

Crush has mechanical and electrical safety features. Mechanical features of strain reliefs, caging to prevent user appendages from slipping into thrusters, and waterproofing were implemented. Electrical safety features of fuses and Blue Robotics Bar30 Pressure Sensor depth sensors to watch for leakages were implemented.

Operational Awareness

This Jobsite Safety and Environment Analysis (JSEA) is engineered strictly for pool-side operations at the World Championship, completely omitting shop/manufacturing safety as mandated by the 2026 competition manual. It explicitly addresses the dynamic hazards of the three specialized operating environments: the wave tank, flume tank, and ice tank.

Finances

Budget & Cost Analysis

As a first-year organization, Devil Fish Robotics operated under limited financial resources during the early stages of development and did not secure sponsorship support until later in the semester. Because of this, careful budgeting and cost management played a significant role throughout the development of Crush and Squirt. Component selection and manufacturing decisions were initially evaluated based on affordability and availability in order to minimize costs while maintaining system reliability and functionality.

Projected Budget

Category	Description	Projected	Actual
Lab Safety	Items used for shop safety. i.e items include safety glasses, first aid kits, etc.	125.00	85.00
Tooling & Equipment	Items used in the lab for fabrication, designing, etc. Includes replacement parts or supplies. i.e. items include multimeters. etc.	600.00	250.00
Research & Development	Prototypes and materials used in our iterative design process. i.e. props, prototypes, sensors, etc.	3,000.00	1,660.00
ROV Surface Structure	Items used for the surface side portion of the ROV. i.e.case, computer, controllers, etc.	100.00	114.00
ROV Structure	Items used for ROV frame, tether, and pressure hold. i.e.frame, pressure hold, O-rings, etc.	400.00	313.89
ROV Electronics	Items used for the internal electronics for the ROV i.e. onboard computers, cameras, sensors, etc	800.00	1,041.07
Float	Float materials electronics, and more. i.e. onboard computer, sensors, materials, etc.	500.00	150.00
Team Operations	Items used to run the team. i.e. shirts/polos, merch, website hosting, projector, etc.	300.00	150.00
Science Initiatives	Items used to support Devil Fish Robotic's science endeavors, including research materials	250.00	-
Competition Logistics	Shipping costs for checking in luggage with the ROV, for the competition.	400.00	384.46
Competition Fees	Registration fees for the MATE ROV Competition.	675.00	675.00
Competition Travel	Transportation and lodging for attending the MATE ROV international competition.	15,000.00	13,538.58
Other	Other	0.00	1,560.77
Total Category	Total Description	22,150.00	19,922.77

Table 7. 2025-2026 projected budget allocations

-itemized cost list will be in appendix

- Descriptions of budget planning and following
- -travel expenses (estimates should be in USD)
- Cost accounting

- Expense distinctions (purchased or donated)
- Income sources and estimates of the fair market value of donations
- Accounting reflected effected use of funds

References & Acknowledgments

DevilFish Robotics' operations would not be possible without our sponsors. We thank the following organizations and individuals for support in the 2026 MATE-ROV competition:

- **MATE** for the organization and planning of the 2026 MATE-ROV competition, allowing us the opportunity to apply scientific, engineering, and technical skills towards real-world applications of ROVs.
- **Dr. Anoop Singh** for oversight as Fulton advisor.
- **Ira A. Fulton School of Engineering** for workshop space in the ASU Drone Studio, Machinestop, and Engineering center E-spaces
- **Larry Lukis Foundation** for their financial contribution allowed for the full build of Crush and Squirt to have been designed, manufactured and tested and for the DFR team to travel to the MATE-ROV competition in St. Johns, Newfoundland and Labrador.
- **3Dconnexion** for their supply contribution of the Spacemouse, utilized for CAD and testing.
- **Alina McNeal, Ricky Donaldson, Bo Ingram** for assistance with supply ordering and finance management.
- **ASU Global Education Office** for assistance in travel coordination, finance management, and administrative guidance.

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$$[11] I_G = \int r^2 dm, \Sigma M = I_G \alpha$$

Appendix A: Standard Operation Procedures

Standard Operating Procedures ensure that safety guidelines are followed and that all employees are able to reference procedures prior to ROV Operations and Assembly. Section A must be abided by at all times in the workspace while additionally PPE and procedures are required during the relevant events stated below.

A. General Safety Guidelines

- ☐ Supervision under a team lead (personnel with shop access and completed lab safety training) is **required**.
- ☐ Closed toed shoes, pants, and tied back long hair are required.
- ☐ **No** food or drinks are permitted in the workspace.
- ☐ Worksurfaces should be devoid of debris and dry.

B. Manufacturing

- ☐ When utilizing soldering irons, required PPE are gloves and respirators. Fume hood must be on.
- ☐ When machining aluminium or steel, all parts must be deburred or filed to remove sharp edges. When utilizing the *ASU Machine Shop* additionally PPE of safety goggles must be worn.

C. ROV Assembly

- ☐ Ensure O-rings are free of debris and thoroughly coated in lubricant.
- ☐ Pressure plug must be open
- ☐ No wiring should be pinched between components and acrylic casing.
- ☐ No wires must be inside thruster enclosures.
- ☐ Components can not be connected to power.
- ☐ All hardware and wiring must be dry and electronics should be devoid of debris.
- ☐ Pressure plug must be closed once other assembly tasks are completed.

D. ROV Disassembly

- ☐ Pressure plug should be open.
- ☐ Components can not be connected to power.
- ☐ External portion of the ROV must be dry.
- ☐ Worksurfaces should be devoid of debris and dry.

E. Leak Test

- ☐ *Section A of F. ROV Operations* must be completed prior to these steps.
- ☐ Ensure pressure is not increasing within the ROV enclosure.
- ☐ Leak-test should be conducted for no less than an uninterrupted 30 seconds environment. Leak-test must be supervised or conducted by the Deck Manager.
- ☐ Pressure within enclosure must remain -15inhg with .5inhg tolerances through the leak test.

F. ROV Operations

A. **T-minus:** Time span which ROV is being prepped to deploy into water

- ☐ Minimum of 3 employees (Deck Manager, Tether Manager, Pilot) and maximum of 5 employees must be present poolside to ensure safe handling of the ROV.
- ☐ Deck Manager **must** be present and confirming the following tasks have been completed.
- ☐ Ensure the ROV is powered off.
- ☐ Ensure frame is **not** cracked, acrylic casing is **not** damaged, components are sealed within the acrylic case to ensure leaks do not occur.
- ☐ Ensure laptop and controller are connected
- ☐ Ensure camera is functioning properly.
- ☐ Components within the acrylic frame must be secured to aluminum plating.
- ☐ All attachments (thrusters, tether, pneumatic arm) must be secured.

- ☐ Tether must **not** be tangled and should be neatly laid for ease of deployment of the Tether Manager.
- ☐ Power supply is dry and not waterside to ensure ground fault does not occur.
- ☐ All personnel must be abiding by general safety guidelines.
- ☐ Recover equipment must be easily accessible by an employee.
- ☐ Tether staging area and control zone must be clear of debris and **only** contain required personnel. This must be confirmed by Deck Manager.
- ☐ Leak-test (*Section E.*) must now be conducted if ROV has not been leak-tested post-last Assembly.
- ☐ ROV should be powered on.

B. Green Zone: Time-span in which pilot is operating the ROV

- ☐ Pilot should inform all personnel that the “**ROV IS LIVE**”
- ☐ Pilot should **not** pilot the ROV until all personnel have heard that the ROV is live.
- ☐ Tether Manager must supervise tether operations while the ROV is in the Green Zone.

C. Red Zone: Time-span in which pilot **stops** operating the ROV

- ☐ Pilot should inform all personnel that the “**ROV IS SAFE**”.
- ☐ Personnel should **not** approach the ROV until the pilot has informed employees that the ROV is safe.

D. T-positive: Time-span in which ROV is removed from the water

- ☐ Ensure that the removal zone is free of debris and confirmed by Deck Manager
- ☐ Confirm that ROV is **not** being operated by the Pilot.
- ☐ Pull ROV from the water.
- ☐ Turn the ROV off.
- ☐ If ROV was operated in **salt water** rinse with freshwater.
- ☐ Ensure the ROV is completely dried before opening acrylic casing.

**All Employees additionally follow the relevant Arizona State University Environmental Health and Safety Guidelines (EHS) in any ASU workplace including the ASU Machinestop, ASU Chandler Innovation Center, Engineering Center E-space, ASU Drone Studio, and Sun Devil Fitness Center [5].*

Appendix B: Lab Safety Policy

1. **NEVER WORK IN THE LAB WITHOUT LEAD SUPERVISION.** Working alone with hazardous materials, equipment, or manufacturing processes is strictly prohibited. All fabrication, machining, and diagnostic tasks must be explicitly authorized and supervised by a designated Principal Investigator (PI), Shop Supervisor, Shop Monitor, or authorized Lead Personnel with active shop clearance [ASU EHS 123].
2. Wear lab-appropriate clothing and personal protective equipment (PPE) at all times within active zones. Minimum compliance mandates high-traction, completely closed-toed shoes, long pants, and ANSI Z87.1+-certified high-impact safety glasses with side shields [ASU EHS 105]. Loose garments, unfastened sleeves, ties, rings, watches, or jewelry are strictly prohibited near active machinery, and long hair must be mechanically tied back behind the shoulders [ASU Fulton Shop Safety Guidelines].
3. All injuries, accidents, or near-miss conditions—regardless of perceived severity—must be reported **immediately** to the Shop Supervisor or Shop Monitor. For all severe injuries, unexpected hazardous releases, or acute incidents, personnel must immediately contact university emergency services and initiate an official incident report [ASU EHS 115].
4. If you are in doubt as to a proper or safe operational procedure, **stop work immediately** and request explicit guidance. Personnel are strictly barred from initiating operations on any milling machine, lathe, or specialized assembly platform unless they have completed the specific ASU shop training and practical verification modules for that tool [ASU Fulton Development Shop Policy].
5. Report unsafe, damaged, or hazardous conditions to shop staff wherever noted. When equipment malfunctions or structural compromise occurs, authorized personnel must immediately isolate the machinery using established ASU lockout/tagout (LOTO) procedures; unauthorized personnel must never attempt to perform LOTO or bypass built-in safety interlocks [ASU EHS 117].
6. Eating or drinking is strictly prohibited within all active lab, shop, and machining spaces. No food, snacks, or beverage containers may enter the work zones to mitigate the risk of chemical ingestion or cross-contamination [ASU EHS 104].
7. Be thoroughly knowledgeable concerning the specific equipment you are using. Personnel must locate, verify, and confirm full functionality of all localized machine controls, emergency kill switches (E-stops), and active mechanical guards prior to tool activation [ASU Facilities and Shop Safety Protocol].
8. Use tools and machinery for their intended engineered purpose only. Modifying a tool or deploying it outside its designated structural, material, or rotational operational limits is strictly prohibited [ASU Machine Shop Operating Guidelines].
9. Do not use fingers or hands to remove chips, swarf, or dynamic debris from moving or stationary machinery. All clearing operations must be performed exclusively using approved mechanical brushes, chip hooks, or specialized push sticks [ASU Fulton Machine Shop Operations].

10. Never adjust, oil, repair, or calibrate a moving or rotating machine. Always isolate the power supply, follow electrical safe work practices, and allow the dynamic components to come to a complete, unassisted standstill before making physical contact or setup adjustments [ASU EHS 117; ASU EHS 118].
11. Never leave a machine running while unattended. The operator must remain actively focused at the workstation until the machine is fully powered off, isolated, and all rotational or kinetic motion has ceased completely [ASU Shop Safety Program].
12. Do not attempt to slow down, brake, or stop rotating or moving equipment using hands, rags, or unauthorized tools. Let the spindle, blade, or chuck coast to a stop under its own accord after turning the power switch off [ASU Machine Shop Operating Guidelines].
13. File, deburr, or finish all machined parts and raw stock immediately post-processing. Acute structural edges, sharp corners, and burs must be eliminated to mitigate personal laceration hazards or damage to assembly components [ASU Machine Shop Design Guidelines].
14. Always clamp, secure, or fixture the workpiece properly before starting a cut. Utilize a heavy tabletop vise, structural clamps, or parallels on the machine table; **NEVER** hold raw stock by hand during active machining [ASU Machine Shop Operations].
15. Use appropriate respiratory protection when working with dusts, mists, fumes, or volatile organic compounds (VOCs). Heavy sanding, welding, soldering, or thermal processing must be conducted within localized exhaust systems, active fume hoods, or well-ventilated spaces [ASU EHS 107; ASU Chemical Safety SOPs].
16. Read and reference the Safety Data Sheet (SDS) for all lubricants, resins, adhesives, solvents, or chemicals you are handling. Personnel must strictly follow the prescribed chemical handling, containment, PPE, and waste disposal protocols [ASU EHS 103; ASU EHS 104; ASU EHS 401].
17. Concentrate fully on the task you are performing. Do not talk to others, use unauthorized personal electronics, or allow yourself to be distracted while operating power tools or heavy equipment [ASU Fulton Shop Safety Guidelines].
18. Use proper lifting techniques and obtain mechanical assistance or teammate backup when lifting, moving, or transporting heavy or irregular structural loads [ASU EHS General Safety Guidance].
19. Watch for and immediately isolate tripping hazards. Keep the floor space surrounding machines entirely clean, dry, and free of cords, raw materials, or debris; never place objects in thoroughfares or egress paths [ASU Facilities and Shop Safety].
20. Know the exact location of all local fire extinguishers, emergency fire exits, emergency eye showers, first aid kits, and shop communication stations before commencing any laboratory work [ASU EHS 104; ASU EHS 200].

Adapted from the Arizona State University Environmental Health and Safety Manual (EHS 103, 104, 105, 107, 115, 117, 118, 123, 200, 401) and the ASU Ira A. Fulton Schools of Engineering Machine Shop Safety and Design Guidelines.

Appendix C: Bill of Materials and Finances

Funds Available (2025-2026)

Category	Description	Actual
School funding	ASU Funding from the Ira Fulton School of Engineering Dean Funding	0.00
Sponsorships	Financial donation from Larry Lukis Foundation	25,000.00
Grant	Grant funding from ASU	0.00
Sponsorships	Physical donation from 3Dconnexion	180.00
Donations	Club members purchasing and donating equipment	500
	Total Category (USD)	25,680.00
	Funding Process Fees (%)	1284
	Total (USD)	24,396.00

Itemized ROV Cost:

Category	Type	Item(s)	Description	Est. Value (USD)
Propulsion	Purchased	Blue Robotics T200 Thruster (x4)	7-20V operating range; 5.1 kg-f thrust @ 12V; MATE-specific penetrators.	\$780.00
Propulsion	Donated	Blue Robotics T200 Thruster (x4)	7-20V operating range; 5.1 kg-f thrust @ 12V; MATE-specific penetrators.	\$780.00
Propulsion	Purchased	Blue Rototics Electronic Speed Controller (x4)		\$160
Propulsion	Donated	Blue Rototics Electronic Speed Controller (x4)		\$160
Control	Purchased	Cube Pilot Orange+	Triple-redundant IMU; vibration-dampened; ArduSub firmware compatible.	\$376.07
Computing	Purchased	Raspberry Pi4+	High-speed USB bus; Linux-based BlueOS; DHCP server functionality.	\$95.00
Vision	Purchased	Arducam 1080p USB Camera	Sony IMX291 CMOS; 0.001 lux low-light; 160° fisheye lens; WDR support.	\$70.00
Sensor	Purchased	Bar30 Pressure Sensor	I2C interface; 30 bar (300m) depth rating; 2mm depth resolution.	\$100.00
Sensor	Purchased	H-Flow Sensor	Real-time current/voltage flux monitoring for failure prediction.	\$45.00
Structure	Purchased	HDPE Frame Panels	CNC-machined High-Density Polyethylene; corrosion-resistant; near-neutral buoyancy.	\$168.89
Structure	Donated	Aluminum Extrusion	2030 and 2040 profiles; longitudinal	\$80.00

			rigidity; standardized mounting.	
Housing	Donated	Acrylic Pressure Hull	Custom acrylic tube; aluminum backplate heat sink; O-ring sealed.	\$503.00
Pneumatics	Purchased	Solenoid Manifold & Actuators	Dual high-response solenoids; 1/4" OD lines; 2x linear cylinders.	\$340
Structure	Donated	Tether	75m length; 12AWG power; Aerial Ethernet; 1/4" pneumatic lines; Foam rope.	\$325.00
Surface	Purchased	Xbox One Controller	HID-compliant; precision analog joysticks for vectored thrust control.	\$60.00
Structure	Manufactured	3D printed parts	Manipulator arm claw, mounts for add-on equipment, and enclosure mounts	\$50
Structure	Manufactured	Laser Cut Acrylic Sheet	Mount for pneumatic actuators and throw holes for wire management	\$15
Power	Donated	48V to 12V Power Boards (x2)	custom power distribution boards to step the 48V power source to eight 12V sources for the thrusters	\$250
Structure	Purchased	Nuts, bolts, and other fasteners	Fasteners to assemble the structural components and attach mission equipment	\$120
			Total	\$4,477.96

Electrical Spec Sheets

The T200 Thruster (SKU: BR-102911-003) is a high-performance underwater propulsion unit utilizing a brushless DC motor and a patent-pending integrated ESC for precision depth operations. This specific variant features a pre-installed 4.5mm penetrator, optimized for seamless integration into high-pressure hulls without the need for secondary potting.

Electrical Specifications

Parameter	Value	Notes
Operating Voltage	6V – 20V	Optimized for 3S-4S LiPo
Max Current (Continuous)	25A	At 16V (Full Throttle)
Max Power	350W – 400W	Dependent on cooling and depth
ESC Protocol	PWM (1100–1900µs)	Standard RC signal compatibility
Motor Type	Outrunner Brushless	Sensored or Sensorless variants available

Technical & Mechanical Specifications

Parameter	Value	Notes

Max Forward Thrust	5.1 kgf (11.2 lbf)	At 16V
Max Reverse Thrust	4.1 kgf (9.0 lbf)	Asymmetric propeller design
Depth Rating	300 meters (984 ft)	Standard rating; deeper on request
Housing Material	Polycarbonate/Glass Fiber	Corrosion resistant
Penetrator Diameter	4.5 mm	M10-threaded bulkhead fitting

-
- **Integrated Cooling:** The thruster utilizes a flooded motor design where water acts as the primary lubricant and coolant, necessitating post-operation freshwater rinsing to prevent mineral scaling.
 - **Acoustic Signature:** High-frequency PWM switching and optimized propeller geometry minimize cavitation, providing a low-noise profile critical for sonar-dependent autonomous systems.
 - **Integration Risk:** While the penetrator simplifies assembly, it introduces a single point of failure; verify O-ring integrity with a vacuum test prior to deployment to mitigate catastrophic ingress.
 - **Force Equilibrium:** The thrust-to-weight ratio is industry-leading, yet the inherent torque reaction requires counter-rotating pairs in ROV/AUV configurations to ensure directional stability.

Category	Component	Technical Specifications	Estimated Unit Price (USD)
Propulsion	Blue Robotics T200 Thruster (x8)	7-20V operating range; 5.1 kg-f thrust @ 12V; MATE-specific penetrators.	\$195.00
Control	Cube Pilot Orange+	Triple-redundant IMU; vibration-dampened; ArduSub firmware compatible.	\$250.00
Computing	Raspberry Pi 4+	High-speed USB bus; Linux-based BlueOS; DHCP server functionality.	\$75.00
Vision	Arducam 1080p USB Camera (x3)	Sony IMX291 CMOS; 0.001 lux low-light; 160° fisheye lens; WDR support.	\$70.00
Sensing	Bar30 Pressure Sensor	I2C interface; 30 bar (300m) depth rating; 2mm depth resolution.	\$100.00
Sensing	H-Flow Sensor	Real-time current/voltage flux monitoring for failure prediction.	\$45.00

Structure	HDPE Frame Panels	CNC-machined High-Density Polyethylene; corrosion-resistant; near-neutral buoyancy.	\$150.00*
Structure	Aluminum Extrusions	2030 and 2040 profiles; longitudinal rigidity; standardized mounting.	\$80.00*
Housing	Acrylic Pressure Hull	Custom acrylic tube; aluminum backplate heat sink; O-ring sealed.	\$120.00*
Pneumatics	Solenoid Manifold & Actuators	Dual high-response solenoids; 1/4" OD lines; 2x linear cylinders.	\$220.00*
Tether	MATE Custom Umbilical	75m length; 12AWG power; Aerial Ethernet; 1/4" pneumatic lines; Foam rope.	\$400.00
Surface	Xbox One Controller	HID-compliant; precision analog joysticks for vectored thrust control.	\$60.00

Budget

[illegible]

Non ROV device Doc

Squirt Vertical Profiler

Non ROV Device Design Doc

Design Philosophy

The original design philosophy of Squirt was to create a vertical profiler that is made out of readily available materials using basic tools and simple techniques that could possibly be developed into a kit that can be used for outreach

Mechanical Design

Squirt, is an underwater vertical profiler that is constructed from standard pvc fittings with a **buoyancy engine based on a modified slide repair coupling that is driven with a gear motor sliding in and out changing the profiler's volume.**

Pressure relief is provided by a slip-o-ring fitting built into the slide repair fitting that is designed to open in the event of over pressure. Adjustable Ballast is provided by stainless steel washers located in the lower part of the buoyancy engine that can be easily replaced.

Access to the enclosure is provided by an acrylic top plate located in a PVC union fitting and at the split between the Buoyancy engine and Float Body.

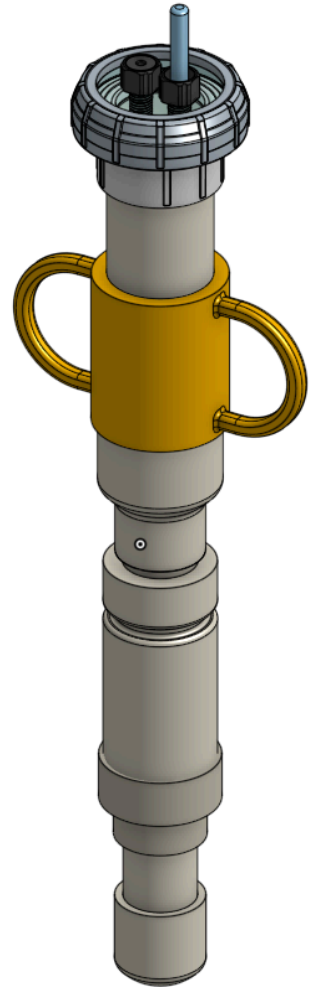
A 3d printed fitting is bonded to the outside with u-bolt shaped grabs at around 2in to allow for easy recovery by ROV assets

Electrical Design

Squirt Utilizes 2 ESP32C3s completing two separate tasks. The main ESP32 interfaces with the pressure sensor and the external antenna to communicate with the base station while computing the buoyancy engine position required to reach and maintain depth. While the second ESP32 is used as a motor controller taking in the desired position, limit switch, and encoder feedback then using a PID loop to command the motor driver to move the gear motor. These functions are separated to allow a more simple programming experience of the Main ESP32. Allowing the profiler to be programmed easily during workshops and outreach.

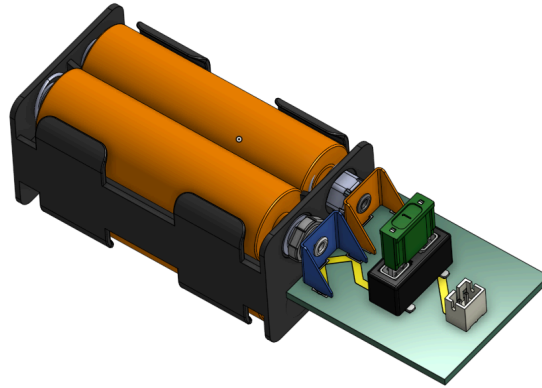
The battery pack is 4xAA batteries placed in a standardized battery holder able support the current and voltage requirements. This is then connected to a custom PC that contains the a industry standard 1amp Minifuse sized to adequately protect the vertical Profiler.

Communication is done through the Main ESP32 using ESP NOW, a broadcast style wifi packet radio standard that allows for easy communication with the top side. A profile cycle is initiated with a profile command then data is transmitted with a data request command



Safety Requirements Verification:

ELEC-NRD-001: The Vertical Profiler is entirely powered from a 4.8V nominal battery pack comprising of 4xAA NiMH Batteries placed in a battery holder with 9V battery clips. A Power fuse



board is directly connected to the 9v battery clips with a 1amp mini Fuse. These fall below the

ELEC-NRD-002: The vertical Profiler makes use of a buoyancy engine and does not contain thrusters or any cameras complying with the requirement

ELEC-NRD-003: Batteries are 4xAA NiMH Batteries that are fused at 1 amp below the maximum of 2A for AA NiMH Batteries

ELEC-NRD-004: Batteries are fused with a 1 amp Mini fuse colored black consistent with industry color codes and is within 1.5 cm of the battery positive terminal connected to a PCB that is directly connected to the battery.

Maximum of 12v and 5Amps

ELEC-NRD-005: The full load amps value is estimated to be as shown in Table 1 below

Mode	Full Load Amps (mA)
Loitering/Transmitting	>100ma
Activated Motor Mode	500ma

ELEC-NRD-006: Pressure relief is provided by a slip-o-ring fitting built into the slide repair fitting that is designed to open in the event of over pressure. The diameter is approx 26mm at that point