QFD Report
Subsea ROV

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ITDE Capstone Design I

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Quality Functional Deployment (QFD)
Project Name: Subsea ROV

Team Introduction

Hudson Hurtig- Project Lead
Hudson oversees the team’s overall direction and ensures that the team is on track to complete milestones on time. He also plans tasks, schedules, and maintains primary communication amongst the team members and the clients.

Luis Lopez- Technician & Technical Support
Luis provides technical support for the assembly and testing of the ROV. He also provides feedback on the proofreading in reports to ensure the technical details are correct.

Juan Lopez- Lead CAD Engineer
Juan leads the CAD engineering efforts and oversees anything having to do with hardware implementation and testing. His expertise ensures the ROV’s physical design is functional

Joshua Mendez - Lead Technical Writer & CAD Designer
Joshua is responsible for technical documentation, CAD designs, and research activities. He ensures accuracy in the documentation and that the written materials are clear, up to date, and professional.

Abraham Rice - Mechanical Development & Presentation Specialist
Abraham focuses on mechanical development while sourcing materials for the project. He leads presentations, meetings, recordings and contributes to building and refining physical components for the ROV.

Ian Wilhite - Lead Integration Engineer
Ian plans the system architecture and oversees the implementation of sensor fusion technologies within the ROV components. He ensures all components integrate seamlessly for the best performance.

Glossary and Acronyms

Tether Wire – Wiring that connects the controls from the surface to the ROV beneath the surface
Subsea – Beneath the surface of the sea (ocean environment)
ROV – Remotely Operated Vehicle
Operator – The end-user providing command inputs and receiving data feeds
End Effectors – Robotic arms on ROV, and manipulators that the robotic arms can command
Motor Controller – the boards that convert high level instructions like RPM, power, or torque to power and signal settings that articulate the motor itself with sufficient energy
Control Unit – the onboard computer that converts user and sensor inputs into digital protocol that the motor controller can understand
PSP – power distribution panel, the panel that distributes the power amongst the various vehicle components such as sensors and various control boards
FET – Forum Energy Technology
COTS – Commercial off the shelf
GB- Gigabyte
GCS- Ground Control System
DVR- Digital Video Recorder

Introduction

The modern economy relies on manmade subsea structures and operations. From telecommunications to oil and gas, to disaster recovery, to transit and shipping, military and more, as our economies grow our presence in the subsea world grows too. A critical cost driver in these industries is the accessibility of the subsea environment to our traditional operating procedures and construction methods. It is expensive or sometimes impossible to maintain subsea structures using manpower in the form of a diver for hours, submarines, or other surface-based operations. This cost barrier, and physical limitations of the human body in subsea environments, is the impetus for developing more cost-effective methods of performing work in these limited environments. One way in which industry has begun to innovate in this field is through the use of subsea ROVs (remotely operated vehicles). By using these underwater robots, work that would be cost prohibitive, unsafe, or impossible to deploy divers, becomes within reach. The new frontier in this industry is defined then by the ability to produce ROVs that are cheap, and easy to use and reuseable. The number of engineers operating in this field are limited relative to the size of the workload and economic importance of subsea industries. From this immense need, charitable institutions have been founded on promoting work within this field to advance the technological frontier of the subsea industry.

As a continuation of a multiyear effort to produce a ROV system, this years group is tasked with building a functional ROV system from an existing subset of components. Primary targets include the design and construction of a Remotely Operated Vehicle (ROV) with diver-like capabilities. ROVs have replaced divers in extreme depth applications because of safety concerns and environmental conditions including extreme pressures and corrosive environments. Many state-of-the-art ROVs experience hardware limitations including camera resolution, haptic feedback, and mobility challenges. The purpose of this project is to see what can be done to remove some of those limitations.

Need Description

The purpose of this section of the document is to describe the needs of the customer and how they have broken down into engineering tasks.

Need Statement

A critical cost driver in economy defining industries is the accessibility of the subsea environment to our traditional operating procedures and construction methods. It is expensive or sometimes impossible to maintain subsea structures using manpower in the form of a diver for hours, submarines, or other surface-based operations. This cost barrier, and physical limitations of the human body in subsea environments, is the impetus for developing more cost-effective methods of performing work in these limited environments. One way in which industry has begun to innovate in this field is through the use of subsea ROVs (remotely operated vehicles).

This year's team will design, construct, and test a Remotely Operated Vehicle (ROV) body, chassis, and propulsion system with diver-like capabilities. ROVs have replaced divers in extreme depth applications because of safety concerns and environmental conditions including extreme pressures and corrosive environments. Many state-of-the-art ROVs experience hardware limitations including camera resolution, haptic feedback, and mobility challenges. The purpose of this project is to see what can be done to remove some of those limitations.

Need Analysis

Statements made by our clients highlighted key aspects of what was originally expected of the robot.

1. "Need to design and build an ROV that can traverse underwater using a 360-degree camera"

   While was is still of great importance for the final design, it was clarified to us that a fully interactive camera system with its specs is not the first feature to be established. Our clients want us to accomplish other priorities within the timeframe we have

2. "Need to Design a highly maneuverable subsea ROV capable of camera attachment"

   This was always central to the vision of the outcome of the project. Emphasis was placed on the maneuverability of the ROV, with less emphasis on attachments required. Though the previous capstone team had a concept in place to tackle maneuverability, the limitations of the design became apparent to the current team and thus a greater need for improvement to be done.

3. "Need to design <u>and construct</u> a compact, highly maneuverable subsea ROV that can later be made compatible with attachments such as arms and camera"

   The top priority of our project is making the ROV maneuverable and easy to control. The last group was able to design the ROV and build the frame. Finishing construction of the ROV, even if redesigned, will progress the project further so future designers can work on enhancing the capabilities. However, we should leave room for compatibility so that future designers can add attachments like the camera and the end effectors. Without knowledge of how the ROV will maneuver, the proper methods of connecting and balancing attachments are unknown

4. "Need to design and test a fully functional Control system to empower vision, maneuverable movement, and future components of subsea ROV."

   Realization and implementation of an actual electronic system is crucial to the actual integration of all previous design features. Without creating an electronic control platform for the ROV, there would be no effective way to test and understand how one feature actually effects the other.

Background Research

Goals for this background research is to inform the client that the team has researched thoroughly for the project to ensure there is a trust connection between the team and client. It also provides a basis to the team of how ROV design is commonly approached and the state of the industry. This research is not only useful as a guide to ROV design but also provides a framework for how we can communicate innovative ideas to those familiar with ROV and see where our design fits in the ROV industry.

Industry Research

Oceaneering makes Subsea ROVs with robotic functions such as limbs for interacting with objects and scanners for inspection of underwater system components. The ROV that we are making would be considered a Micro-ROV in this project. Our correspondence with Technadyne, the supplier of our main ROV motors and components, has driven much of the design conversation around all of our control systems and end effector designs.

The ROV market size is projected to be worth 6.2 billion in 2033, growing at a compound annual growth rate of 11% from 2.2 billion in 2023. Enhancements in ROV technology including automation, navigation, and data processing improvements increase the value of ROVs, as well as an increase in their applications in defense.

Patent Research

The group reviewed the U.S. Patent US 11,405,548 that describes a tethered underwater ROV equipped with 360-degree cameras and a thruster configurator to enable maneuvering for maximum convenience. This approach supports the project goal of obtaining maximum visibility and control in an underwater scenario. The ROV that the group is currently developing will incorporate a similar camera layout by mounting the panoramic camera at the top of the ROV. The Patent emphasizes sealed optical enclosures, also informing the group that the Camea housing and wiring routes are designed to prevent distortion and water intrusion. By applying the camera and control concepts to the project, it can be ensured that the ROV will achieve a high-quality picture and navigation.

AI Based Research

ROVs work in systems, where the vehicle portion of the system is what travels underwater while the tether/umbilical connects the ROV to the control station, transmitting power, data, and video signals. The control station will be present on a vessel if offshore, and is a set of monitors, controls, and other electronics that enable operators to control and see what the ROV sees.

The subsea ROV industry is growing as offshore activity increases for multiple sectors. With the advancement of AI, the industry is moving towards more autonomous iterations. There are already automated underwater vehicles, but such AI integration could provide advanced capabilities to highly maneuverable ROVs.

Some challenges of ROVs are high costs, high skill requirements, harsh operating conditions, and risks associated with the systemic nature of ROV operation.

General Research

Simple underwater ROVs can be made DIY with tether wire, semi buoyant protective casing for electronic components, and motor control. Video feeds also fed through wire as well, as wireless signals tend not to travel well underwater.
ROVs are typically used for maintenance and surveillance work in industries such as aquaculture, oil, infrastructure, and offshore energy. They are also used for exploration, recovery, and science, and have additional survey capabilities such as 3D sonar.

Quality Function Deployment and House of Quality

Introduction:

Taking our client's objectives in direct consideration, we began to match customer specs with the engineering specs required for the submersible craft. We created a house of quality to get a better perspective on our priorities for the design in terms of what components will be focused on and their relationships with other components/systems. Maneuverability and Visibility were the direct highlights of our clients. They the need for full directional movement in general drive scenarios and in close quarters. Additionally, they specified the capability of the ROV to allow the operator to see and perceive its surrounding environment. The ease of operation and project construction factors flowed from the first two factors, prioritizing solid controls to take advantage of maneuverability. Current giants in the industry such as Oceaneering and FET also put high priority on maneuverability, being a continuous design problem for the trade. Another factor that has surfaced from both client discussion and industry research is a triage of design considerations. It is best to design the ROV to not fail during operation, requiring robust testing of the core power and motor systems. It is the second best to design the ROV to be retrievable from the field and thus repairable.

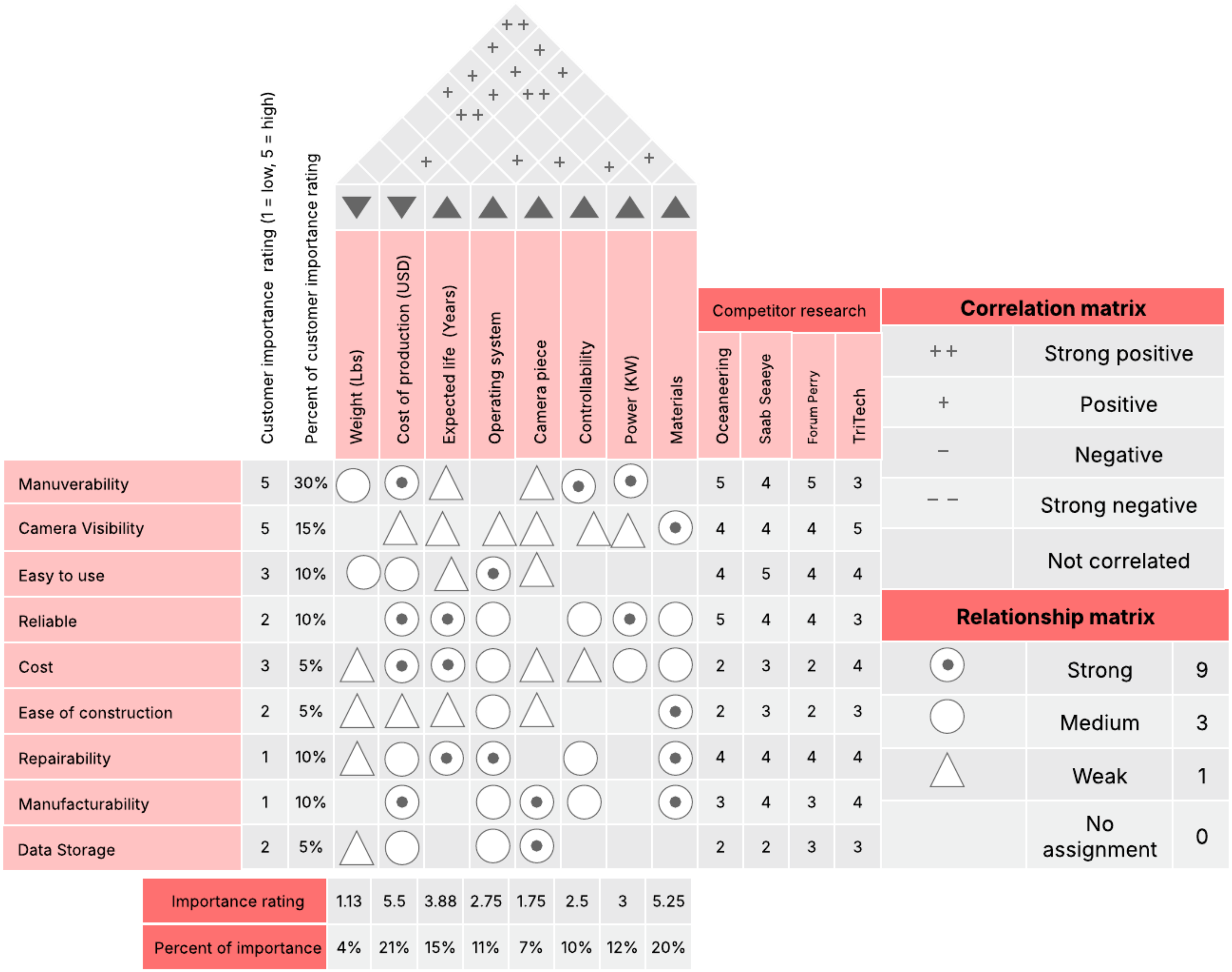

Figure 1. House of Quality Chart for Subsea ROV

Functions Description

The following covers the functionality of the ROV displayed in figure 2 with additional information just below. As the Function diagram has 5 functions under one need statement. And within each section with multiple sub sections of the functions listed below that.

Functional Diagram

The functional structure defines the essential actions that the Remotely Operated Vehicle (ROV) must perform to satisfy the project's **House of Quality (HoQ)** priorities and overall need statement: *"Design, construct, and test a rover body, chassis, and propulsion system."* Each function represents an outcome the **design itself** must achieve rather than the actions of the design team. The function hierarchy ensures that all customer needs—maneuverability, reliability, usability, and cost-effectiveness—are translated into measurable engineering objectives. It serves as a roadmap linking stakeholder expectations to technical implementation.

At the highest level, the ROV must **traverse its environment**, **perform inspections**, **provide an intuitive interface**, **remain reliable and repairable**, and **maintain low cost**. These top-level functions are decomposed into second-level functions that specify performance and design metrics. For example, traversal includes six-degree-of-freedom propulsion, stable control, and a 50-foot operational range. Inspection encompasses a 360° camera, telemetry latency under two seconds, and data recording capacity of 25 GB on the Ground Control Station (GCS). The ground control station should serve as a Digital Video Recorder (DVR) for incoming video streams, telemetry data, and user inputs. Ease of use is supported by intuitive commands, commercial off-the-shelf (COTS) input devices, and minimal training time. Reliability requires a five-year lifespan, COTS components, and standardized interfaces, while low cost emphasizes manufacturability, sub-$2,000 construction, and the absence of consumables.

Together, these interrelated functions form a complete system framework guiding subsystem development, design trade studies, and verification planning. Future work will refine lower-level functions (e.g., thruster configuration, sealing mechanisms, and onboard power distribution) and develop functional flow diagrams that model how energy, control, and information move through the ROV during operation.

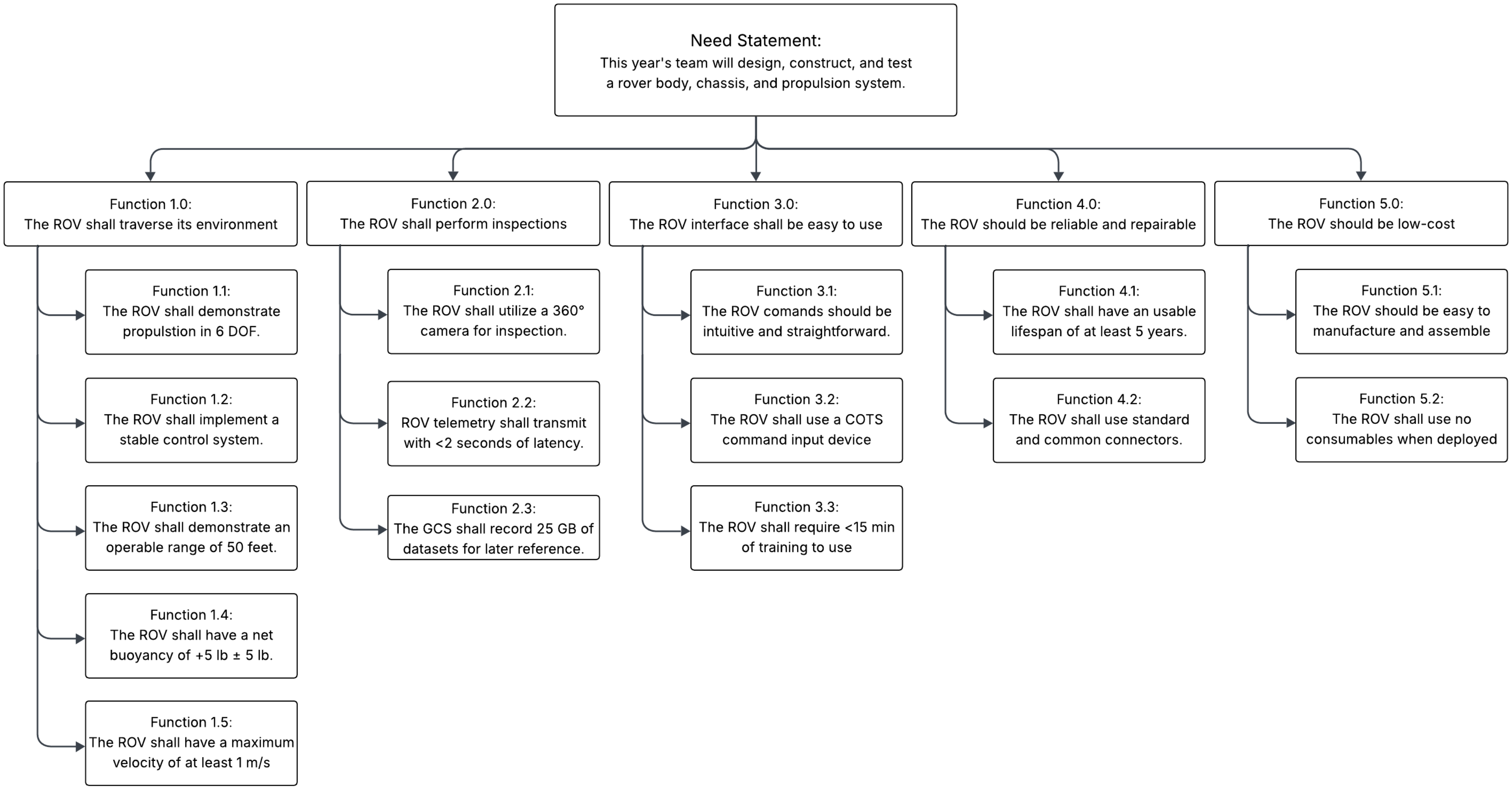

Figure 2. Function Structure

Functions and Engineering Science

The objective of this section is to establish clear and defined ideas for connecting the main ROV functions to their engineering sciences. The functions will be further analyzed by determining if the defined design parameters are met or can be systematically observed.

Defining of Table Contents:

- Function:
  - The primary capabilities of the Subsea ROV. These are obtained through sponsor specifications
- Performance/Specification Requirements:
  - quantifies the function, generally "how?" the function will be achieved. Allows for a sort of benchmark to be used for testing and validation of functions
- Parameters:
  - Design variables or physical properties that can be altered to achieve the design requirements. These present a tangible design choice
- Analysis:
  - To identify the core engineering and scientific principles used to validate the design. Also, the theoretical application to prove the chosen parameters will meet the design specifications.

Overall, this section is to generate a structured and traceable flow between the design decisions to their specific functional needs. Achieved through clear verification processes pertaining to measurable performance benchmarks. Following this process will reduce deign risk and ensure that the final project is cohesive, optimized, and a reliable solution to our sponsors' operational needs.

Function	Performance/Specification Requirements	Parameters	Analysis
Maneuverability	-Full Instantaneous 6 DOF -Redundant Thruster Configuration	Motor location and orientation relative to center of pressure and center of mass	-Control basis reports -Kinematic modeling, inertia, and CG and CP transient calculations
360 Degree View	-Live feed of 360 views -High real-time quality image	Can we “see everything”?	-View Obstruction -Camera feed uptime, resolution based on stream rate
Structure & Repairability	-Withstand water depth pressure up to 20 ft -House all driver components -Support thrusters -Repairability	-Material selection -Connections and Fastenings -Geometry (hull and mesh) -Total Cost	-Failure mode analysis? -Does water Leak? Y/N -Depth testing and gasket rating analysis
Power	-Be able to deliver the 300V (current variable) specification to each thruster -On board battery -Power distribution board	-Power Consumption -Volts and Amps with Time -Heat Dissipation -Tether size and length	-Power efficiency -Do electronics stay within operating temperature
Controls & Data	-Have an active bandwidth to thruster distribution controller -User interface/controller -Storage device for data	-Software -Onboard Computer -Integration -Ease of Use	-System integrity -System diagnostics -Low training time -Control and feedback coding, data management, UX and UI

Summary

This report outlined the Quality Function Deployment (QFD) process undertaken by the ITDE Subsea-ROV team to design a compact, highly maneuverable Remotely Operated Vehicle (ROV) for subsea operations. The team analyzed client and sponsor needs, translated them into engineering specifications, and structured the system's functional requirements through the House of Quality and function structure diagrams. Research into existing ROV technologies, patents, and industry practices provided the foundation for establishing performance goals and design priorities.

Through this phase, initial design concepts have been developed and aligned with client expectations, and a follow-up meeting is planned to review design feasibility and gather sponsor feedback. Strengths of the current design include clear functional decomposition, realistic engineering objectives, and an adaptable framework for future system enhancements. Moving forward, the team will refine subsystem integration and conduct prototype testing to validate design performance against identified specifications. The design and testing efforts will primarily focus on the integration of power and thruster systems, for which design challenges have presented themselves in the form of power draw estimations and proper integration with motor systems.

Appendix

Include references, secondary graphs, charts, or other items that don't necessarily fit into the main body of the report.

U.S. Patent No. 11,405,548 B1. (2022). Remotely operated underwater vehicle with modular camera housing and vectored thruster configuration. U.S. Patent and Trademark Office.

Sources for research section

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