3. DESIGN APPROACH

This section allows for an in-depth analysis of the design process behind the creation of JellyBOT. The team developed a remotely operated vehicle (ROV) to mitigate underwater trash accumulation in freshwater. To realize this goal, the team considered multiple design options, system organization methods, and quality parts options before deciding on the robot's final iteration. Through research and group discussions, the team modified initial design choices to fulfill set requirements, constraints, and industry standards. The most heavily emphasized requirements include complete waterproofing, operation for 12 hours on a single charge, internal and external water pressure tracking, and minimal damage to the environment. This section depicts the detailed thought process behind the team's chosen solutions and initial ideas. By investigating multiple design options and subsystems, the team intends to provide a total understanding of the operations of the JellyBOT.

3.1. Design Options

The team examined several design options to find the best and most reliable method for constructing the JellyBOT. From the team's initial proposal of a fully autonomous robot that could clear all freshwater environments to the proposal of a semi-autonomous robot that could clean smaller bodies of freshwater, there were many advantages and disadvantages to consider. The team ultimately chose the current design as it would be more feasible considering the time constraints as well as the many disadvantages that the project could possibly have.

3.1.1. Design Option 1

The initial solution the team proposed was to have the top of the robot be a mesh net to collect large underwater pollutants. The mesh net would be malleable, allowing for more space to collect trash with minimal concerns for tearing or breaking. This solution would mean a larger robot as most of the space would be used for collection. The initial solution also did not need an internal water pressure sensor, as the compartment that would hold the trash would be porous, allowing for water to exit the compartment as it was filled. The electronic components would be compacted into a ring-shaped enclosure at the net's opening and would allow the robot to move freely while the enclosure protected the electronic components. The robot's arms would be mechanical and used for collection and movement, with two tentacle-like arms used to move the robot and four more to collect trash underneath it. There would also be four cameras to allow the user to see the environment the robot navigated and any pollutants that the robot may have missed.

While the porous collection design approach initially proposed by the team offers advantages such as more collection space and a lesser concern for the buoyancy of the robot, it comes with a notable setback in that freshwater environments have copious amounts of algae. In addition, having the electronic components in a ring at the opening of the mesh net draws exponentially more disadvantages, including a limitation in the size of pollutant that could be collected. It would also make emptying the net difficult since certain pollutants would only fit in one direction. It would also create a considerable limit to the number of cameras that could be used, as well as limiting their orientation, which could affect how much of the environment and how many pollutants the user could see. Additionally, there would be a higher risk of the pollutants, if sharp enough, damaging the enclosure containing the electronic components, creating a risk of exposure to electric shock both for the user and the creatures living in the freshwater environment.

3.1.2. Design Option 2

A secondary design solution proposed by the team was to have a non-porous, waterproof, bowl-like structure as the encloser for the electronic components and a collection space for the pollutants. The tentacles would still be used to grasp underwater pollutants, but they would no longer be needed to move the robot as its movement would be controlled via propulsion. The mechanical tentacles would be replaced with a soft actuator system that would allow for air pressure to control when and how the robot's arms opened and closed. As the robot collected trash, water would be trapped in the collection space. To alleviate the internal water pressure and allow for more space to collect pollutants, the collection space would have straw-like tubes that would pull water out to be used to propel the robot in multiple directions.

The main disadvantages of this design were the solid enclosure and the propulsion system. Having a solid enclosure meant having more sensors since the internal water pressure would have to be monitored to control the propulsion system. The propulsion system would have to be both made for suction, in terms of pulling water out of the collection compartment, as well as for jet propulsion to use said water to move the robot, which would be time consuming to design and harder to integrate for a potential user.

Though aspects of this iteration such as a solid enclosure for the electronic components, were implemented into the final design, others, such as jet propulsion, were eliminated or modified to fulfill certain constraints.

3.1.3. Design Option 3

The third design solution that the team considered and took the most inspiration from for the final robotic iteration was a cylindrical set of enclosures for the electronic components with a porous collection space in between them, along with a motor for movement. The arms are still controlled via internal air pressure in the same way as the secondary proposed solution. The reintroduction of a porous collection space was partially inspired by the need for an easier way to collect trash without sensors being needed to monitor the space. The design changed from being vertically oriented to having a similar design to a submarine. The motor allows for simplified movement rather than having the arms moving the robot or having a propulsion system based on internal water pressure. The cylindrical enclosure allows for a compact design that has been proven to work in underwater spaces, and having multiple cylinders allows space for the tentacles' electronic components, and the cameras, and any other components.

Though many aspects of this iteration were adopted in the final design, the porous collection space was never proposed again although it would be helpful to control the robot's internal water pressure. The concern for damage to the collection system and the cylindrical enclosure was considered too great. In addition, the set of cylindrical enclosures would produce the same problem as the initial design as well as force the mesh collection space to be rigid, making it likelier for the bag to be destroyed and significantly limiting the size of trash that could be collected. The set of cylindrical enclosures was changed into a singular cylindrical enclosure in later iterations as the horizontal orientation of the robot allowed for simpler solutions such as arm placement and buoyancy concerns. The porous collection space was also replaced with a solid collection space, which has internal water pressure sensors, and a system to remove water from the collection space via tubes that siphon the water out whenever the tubes' valves are opened.

3.2. System Overview

The JellyBOT is a remote-operated vehicle tailored for underwater trash collection, efficiently powered by a 12-V direct current power source. Its integration of radio signal reception enables a sophisticated remote-control system, granting operators precise control over its movements and functions from a surface location. This feature significantly improves its efficiency in navigating underwater environments and gathering debris. Figure 3-1 visually demonstrates how the JellyBOT responds to received signals by activating either its control or actuation system.

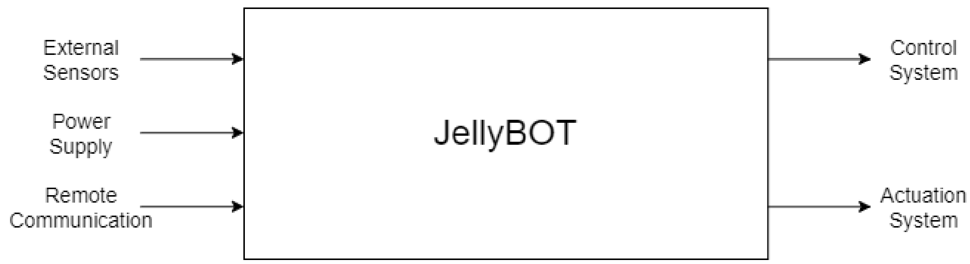

Fig. 3-1: JellyBOT System at a Glance (Level 0)

Figure 3-2 offers a comprehensive illustration of the final JellyBOT, detailing its different subsystems and how they operate when receiving inputs from a remote control, ultimately directing outputs into a specific system.

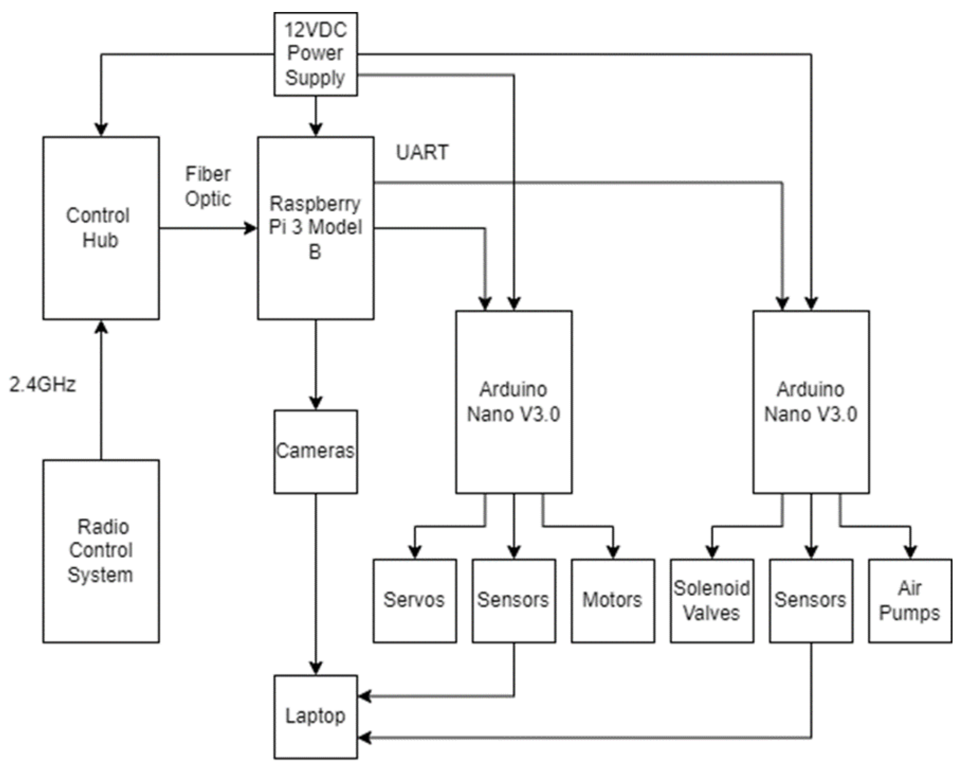

Fig. 0-2: JellyBOT Functionality (Level 1)

The JellyBOT utilizes a control hub to receive radio communication, transmitting signals to a Raspberry Pi 3 Model B. This Raspberry Pi 3 Model B processes video feed captured by a camera and sends it to a laptop. When the remote provides input, the Raspberry Pi 3 communicates data to a receiving Arduino Nano V3 via UART protocol. Within this system, two Arduino Nano V3 units are employed: the first supervises navigation, managing motors, servos, and sensors, while the second governs the actuation system. This setup, including air pumps, solenoid valves, and various sensors, enables efficient trash collection through a soft actuator mechanism.

3.2.1. Microcontroller

For this project, a Raspberry Pi 3 Model B and two Arduino Nano V3s were chosen as microcontrollers.

Fig. 3-3: Raspberry Pi 3 Model B Microcontroller [1]

The Raspberry Pi 3 serves as the central processing unit, enabling radio communication from a remote controller via an Ethernet cable using a fiber-optic-to-Ethernet converter. It interprets inputs, coordinates system functionality, interfaces with peripherals like cameras, and manages power distribution. Its selection is based on its capacity for complex tasks, compatibility with Ethernet communication, and ability to interface with various devices essential for underwater operation.

Fig. 3-4: Arduino Nano V3 Microcontroller [2]

For the control system, an Arduino Nano V3 handles the control of motors and servos, receiving instructions from the Raspberry Pi 3 and translating them into commands for motor and servo control. This microcontroller manages the navigation of the JellyBOT, controlling forward and backward movements, and positioning servos for precise rudder and fin control.

In the soft actuation subsystem, another Arduino Nano V3 oversees the collection of debris. It receives commands from the Raspberry Pi 3 to activate a series of air pumps and solenoid valves, allowing the JellyBOT to collect debris through a soft actuator mechanism. The choice of using separate Arduino Nano V3 units for each subsystem ensures dedicated and efficient control for both navigation and debris collection.

3.1. Subsystems

JellyBOT's design comprises five distinct subsystems, each critical to its overall functionality. These subsystems include:

1. The navigational subsystem of JellyBOT features a remote that controls not only the robot's arm movements but also its overall motion.
2. The actuation subsystem of JellyBOT consists of four fiber-reinforced soft actuators. These specialized components play a crucial role in enabling JellyBOT to collect debris within an underwater environment
3. The power subsystem of JellyBOT is made up of an external power hub, which includes a wireless charging station.
4. The camera and sensor integration subsystem consists of six cameras, an internal water level sensor, and three pressure sensor modules.
5. The propeller subsystem consists of a motorized drive unit that controls a propeller.

These five subsystems work together to allow JellyBOT to move and communicate underwater while collecting small pieces of plastic. In the subsequent sections, each subsystem is explained in detail.

3.1.1. Subsystem 1: Navigation

The navigational subsystem of JellyBOT plays a pivotal role in its overall functionality, serving as the interface between the operator and the robot's movement capabilities. By enabling remote manipulation of the robot's kinematics, including both limb articulation and overall locomotion, this subsystem significantly enhances the robot's operational versatility. This versatility allows JellyBOT to perform a diverse array of tasks with heightened precision and adaptability, making it suitable for various applications. One of the key functionalities of the navigational subsystem is its ability to connect to the Arduino Nano, which serves as the brain of the robot. This connection is facilitated through the remote control's transceiver, which communicates with the receiver within the remote control. This communication link allows the remote control to send commands and instructions to the robot, enabling the operator to control its movements effectively. The navigational system of JellyBOT primarily consists of the remote control and its accompanying transceiver. The remote control is a crucial element, as it is responsible for relaying information to the robot through water, which is the medium in which JellyBOT operates. The remote control has a variety of switches and joysticks, which control the robot's movement. Additionally, the remote control is compatible with the microprocessors chosen for the robot, ensuring seamless integration into the overall system.

There were three options when selecting the remote controller of JellyBOT as depicted in Table 3-1. The design team considered several factors, including cost, range of communication, power intake, transmitter channels, and weight. These parameters were crucial in determining the most suitable remote control for the robot, ensuring optimal performance and efficiency.

Table 3-1: Remote Control Options

Model	Range of Communication	Power Intake	Weight	Transmitter Channels	Cost
Requirements	Minimum of 12 m	≤ 5 volts	< 2.3 kgs.	> 5 channels	< $80
Flysky FS-i6 Model 2 [3]	500 m	< 4.2 V	< 0.9 kgs.	6 channels	$43.75
Flysky FS-i4 [4]	~	< 4.2 V	< 0.9 kgs.	4 channels	$37.99
Radiolink AT10ll [5]	3862 m	7.4 - 15.0 V	1 kg.	12 channels	$158.89
BETAFPV ELRS LiteRadio 3 [6]	~	~	1 lb.	8 channels	$72.99

The Flysky FS-i6 remote control, depicted in Figure 3-5, was selected for use due to its ability to meet the project's requirements. Among the available options, the Flysky FS-i6 stood out because it features a light-emitting diode display, which provides important feedback and control information to the user, as shown in Figure 3-1. Notably, the Radiolink AT1011 was the only other remote control that offered an LED display; however, it was deemed too expensive and fell outside the team's budget constraints.

Fig. 3-5: Flysky FS-i6 Remote Control [3]

The Flysky features an array of switches and controls that are programmed to govern JellyBOT's movements. These controls include joysticks, buttons, and switches, which are customized to enable precise control over the robot's articulation and locomotion.

Additionally, the remote control is equipped with a transmitter, shown to the right of the remote. This transmitter is a crucial component, as it is responsible for transmitting the commands from the remote control to the robot. The transmitter on the Flysky FS-i6 has six channels, which means that it can transmit up to six different commands or signals. These channels provide the team with the capability to give JellyBOT up to five commands, allowing for a high degree of control over its movements and actions.

3.2.2. Subsystem 2: Fiber-Reinforced Soft Actuator

The soft actuation subsystem of JellyBOT is a vital mechanism enabling effective interaction with the underwater environment, especially in debris-collection tasks. This subsystem is meticulously crafted, integrating a range of specialized components chosen for their reliability, durability, and seamless integration with the overall system architecture. At the core of this subsystem is the incorporation of Kevlar thread reinforcement for the soft actuators, selected for its exceptional strength-to-weight ratio and resistance to abrasion, ensuring structural integrity even in challenging underwater conditions.

Fig. 3-4: High-Strength High-Temperature Thread 0.014" Diameter [7]

With a rated voltage of DC 6V and a maximum vacuum of less than 420 mmHg (approximately 1.38 ft), this air pump delivers precise airflow and pressure essential for optimal performance while maintaining compatibility with the power source and adhering to acceptable noise levels.

Fig. 3-4: Micro Air Pump - DC 6V Vacuum Electric Booster, Micro Electric Air Booster for Medical Instruments and Aquarium Oxygen Tanks [8]

Similarly, the mini solenoid valve was selected for its compact design, aluminum construction, and suitability for automatic control applications. With a diameter of 0.12 inches, it provides precise control over the flow of air to the actuators, facilitating the grasping motion required for debris collection underwater.

Fig. 3-4: Mini Solenoid Valve, 2 Position 2 Way Normally Open DC 6V 0.24A Electric Solenoid Air Valve [9]

The soft actuation subsystem of JellyBOT is equipped to perform tasks such as debris collection with efficiency, precision, and durability in underwater operations by carefully evaluating and selecting these components.

3.1.2. Subsystem 3: Power

JellyBOT's power subsystem utilizes an assembly that allows for wireless charging as its primary source of power. To facilitate wireless charging, a charging station is on the environment's surface, enabling the robot to charge a lithium-polymer rechargeable power bank or battery exterior from its underwater habitat. The station generates a sustainable energy source transmitted to the robot by an electrical circuit made up of various components. The energy is then transferred from a wire coil receiver and stored in the power bank, which can receive input from a voltage range of 5 volts (V) to 12 V with a maximum amperage range of 3 amps (A). The output voltage of the wire coil receiver is boosted from 5 V and 1.2 A to 12.6 V and 2 A through a voltage and current boost converter to provide the power bank with its specified ratings in voltage and amperage. Strategic placement of the charging station, coupled with the implemented electrical circuit, is essential for efficient charging while keeping the robot waterproof. Regarding the additional components that rely on the power bank, the wiring encompasses vital systems like propulsion, navigation and object collecting sensors, communication systems, and several onboard computing devices. Each element is linked to the power bank via suitable circuitry, guaranteeing a consistent distribution of power throughout the robot's operation.

Table 3-2 provides justification for the selected battery options that can operate alongside a wireless charging source and maintain stability while underwater for approximately 10 hours. The design team collectively examined and discussed battery options that met the objectives while considering internal logic and external location factors. The JellyBot's wireless charging electrical circuit has multiple parts that function effectively, enabling manual recharging without requiring battery replacements.

Table 3-2: Rechargeable Battery Options

Battery	Voltage Rating (V)	Capacity (mAh)	Size (L x W mm)	Weight (g)	Price
Requirements	3 - 15	500 - 50,000	< 50 x 150	< 800	< $50.00
Vicmile USB Chargers RC Battery [10]	3.7	800	51 x14	22	$9.99
EEMB Li Polymer Battery [11]	3.7	2,000	56 x 34.5	40	$13.99
Energizer Power Bank (Batter [12]	12	30,000	40 x 116	680	$39.99

According to the specifications provided, the Energizer Power Bank, shown in Figure 3-6, has the capability to deliver 3 amperes of current for an effective duration of 10 hours, given its rated voltage and capacity. While assuming optimal operating conditions, the power bank provides a reliable and consistent source of power for each electrical component within the circuitry of the JellyBOT. Additionally, the advanced features allow for seamless and optimized alignment with the robot's infrastructure.

Fig. 3-6: Energizer Power Bank [12]

In accordance with Figure 3-6, the liquid crystal display affixed to the power bank accurately assesses the charge status during operation, corresponding to the power bank's capacity. Additionally, the power bank offers fast-charging capabilities, which makes it the ideal choice for sustaining any task without extended charging periods.

Table 3-3 outlines the choices related to the wireless charging wire coil required for efficient energy transfer from the station to the robot. Wireless charging receiver options varied in price and durability, necessitating additional parts linked from the power station to form the power subsystem for the robot. It is important to consider various options, including the widely used Qi standards for consumer electronics and group standards tailored to specific underwater robotics engineering requirements when selecting a wireless charging standard for compatibility with a receiver [28]. Ensuring compatibility with the chosen standard is essential for seamless integration and efficient power transfer. Also, the receiver's design is optimized for the typical operating conditions in underwater environments. Subaqueous conditions include considerations such as the pressure, temperature, and potential interference from surrounding materials or electromagnetic fields. The receiver is rugged and waterproof to withstand the harsh conditions underwater while maintaining reliable performance. Efficiency and power transfer capabilities were considered, as higher efficiency means more effective energy transfer and faster charging times. To maximize the power bank's lifespan and minimize energy waste, the design team emphasized selecting a receiver with optimal efficiency for the intended application.

Table 3-3: Wireless Charging Coil Receiver Options

Receiver	Voltage (V)	Amperage (A)	Wattage (W)	Standard	Price
Requirements	3-10	1-5	5-15	Qi/PMA	$15.00
Gikfun Wireless Charger [13]	5	2	10	Qi	$8.68
Ashata DIY Wireless Receiver [14]	9	1	5	Qi	$8.69
Acxico Wireless Receiver [15]	5	1	10	Qi	$9.99

The Acxico Wireless Charger Coil Receiver, shown in Fig. 3-7, satisfies the requirements listed while also benefiting from an increase in cost for effective part allocation. Also, the receiver contains a printed circuit board assembly attached to ensure proper circuitry from the station to the receiver for adequate energy to flow, recharging the power bank at a faster rate than competing parts.

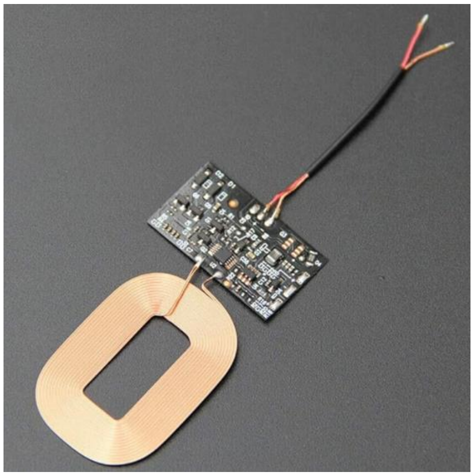

Fig. 3-7: Acxico Wireless Charging Coil Receiver [13]

In Figure 3-7, the coil connection and the wire connection are spliced to the printed circuit board assembly instilling a fundamental approach to the circuit involved with adjustments possible.

Table 3-4 identifies the proper charging connection board that correlates to the chosen receiver in Figure 3-7, capable of supplying the chosen power bank shown in Figure 3-6 with proper voltage and current levels at a regulated output range. Careful consideration of several key factors was necessary to identify the appropriate charging connection board that can boost the input voltage and current to support wireless charging in an electrical circuit connected to a rechargeable battery. The board selected is compatible with the Qi wireless charging standard being utilized to ensure seamless integration with the charging infrastructure. Compatibility is essential for effective communication between the charging station and the circuitry, enabling efficient power transfer. Furthermore, for underwater applications, the charging connection board's ratings, weight factor, and durability are crucial to consider. Limited space and harsh environmental conditions demand a compact yet sturdy board that can withstand the pressures, temperatures, and potential water ingress inherent in subaquatic environments. Evaluating these aspects, the design team collaborated to select the appropriate charging connection board to enhance the input voltage and current, thereby supporting wireless charging within the integrated circuit linked to the chosen rechargeable power bank. This power bank charging method ensures optimal performance and durability in underwater applications.

Table 3-4: Charging Connection Board Options

Charging Board	Output Voltage (V)	Amperage (A)	Weight (g)	Standard	Price
Requirements	5-12	0.5-3	< 8	Qi	$20.00
Aceirmc Charging Protection Board [16]	8.4	1	5	Qi	$6.99
HiLetgo Charging Converter Board [17]	3 - 12	2	6	PMA	$7.99
Treedix Charger Board w/ LED Indicator [18]	5	0.5	3	Qi	$12.99

The Aceirmc Charging Protection Board, shown in Table 3-4, fulfills the requirements above as the optimal solution for managing the transfer of energy from the coil receiver to the rechargeable power bank, resulting in a faster charging process. This protection board is compliant with the Qi standard and fully compatible with the selected coil receiver. Notably, this protection board also boasts a competitive price point, making it an affordable choice for Team Romeo to seek a budget-friendly part option.

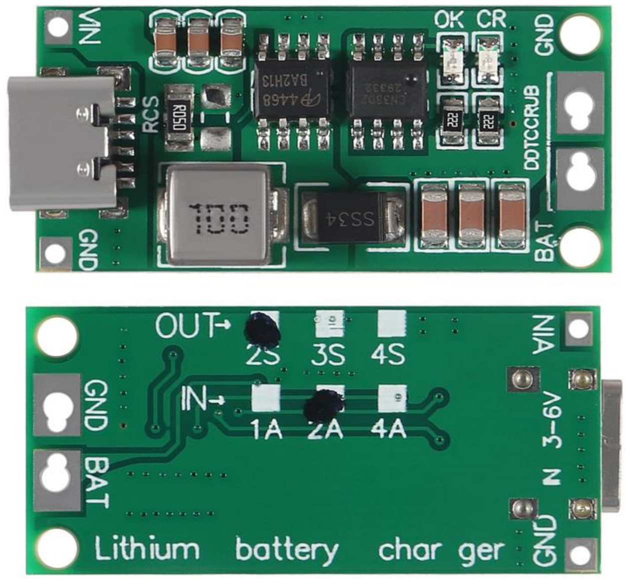

Fig. 3-8: Aceirmc Charging Protection Board [7]

In Figure 3-8, the implementation of the Type-C adapter into the board's design enables the fast-charging quality to be applied, alternatively, for efficient energy transfer to the rechargeable power bank.

3.1.3. Subsystem 4: Camera and Sensor Integration

Camera integration as a subsystem is incredibly important to the robot's functioning. Without cameras, navigating JellyBOT in an underwater environment would become an exponential challenge. By implementing this system, the user can see and understand more about the environment the robot would be in without being underwater. A key functionality of the cameras is the ability to connect them to a laptop or desktop computer. This implementation is made possible through a connection to a raspberry pi which allows any data that comes from the robot to be sent to a laptop via USB or HDMI connection. The cameras are crucial to the robot's operation as they allow the user to act as JellyBOT's eyes while they navigate it through a freshwater environment. The cameras are compatible with the raspberry pi which is then compatible with the microprocessors chosen for the robot.

The sensor integration subsystem allows the robot to control actions such as collection management. The water level sensor allows the robot to release water from the collection area into the environment based on the compartment's internal water level. In addition, two barometric pressure sensors inside the enclosure allow the robot to monitor the robot's internal air pressure, while one sensor determines the external water pressure on the robot. The sensors are compatible with the Arduino Nano V3 as well as all other microprocessors that were chosen for the robot.

When debating the camera options for the JellyBOT, shown in Table 3-5, the team considered individual and total price, simplicity of integration, compatibility, brightness, and image clarity.

Table 3-5: Camera Options

Model	Compatibility	Integration Simplicity	Brightness	Image Clarity	Price Per Camera	Total price
Requirements	Compatibility with a Raspberry Pi	Need for any additional parts	Affected by underwater use	Affected by underwater use	> $30	> $60
MUNEFE Underwater Ice Fishing Camera [19]	Yes	Yes, an external tether system	Yes	Yes	$22.19	$133.14
Notebook Internal Webcam Module [20]	Yes	No	Moderately	Moderately	$9.18	$55.08
Arducam 5MP Camera for Raspberry Pi [21]	Yes	Yes, with a separate multicamera module ($59.98) [22]	Yes	Yes	$9.99 + $49.99 = $59.98 (Including module)	$59.94 + $49.99 = $109.93 (Including module)

The Notebook Internal Camera Module, shown in Figure 3-9, fits within the project's parameters. without being expensive, nor did it need an external module to operate with the Raspberry Pi and Arduino Nano V3. Markedly, if the Raspberry Pi camera did not include an external module, it would have been a viable option for implementation into the robot. However, it was too expensive, fell outside the team's budget, and would have been incredibly difficult to implement for the team as it would be coded in Linux.

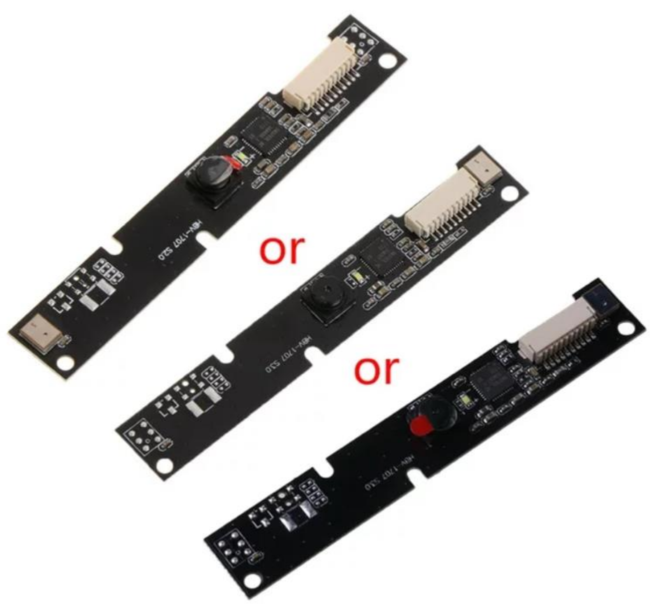

Figure 3-9: Notebook Internal Camera Module [20]

Figure 3-9 depicts a notebook laptop internal camera module highlighting multiple different versions with similar layouts. It displays the parts of the camera that affect its connection to the Raspberry Pi. Though the cameras will be on the outer layer of the encloser, they are not exposed to water in any way. This camera gives the team the capability to monitor the environment the robot will be used to clean and to connect multiple to one Raspberry Pi without a separate module.

When debating the water level sensor options for the JellyBOT, shown in Table 3-6, the team price, water resistance, compatibility, and integration simplicity.

Table 3-6: Camera Options

Model	Compatibility	Integration Simplicity	Water Resistance	Total price
Requirements	Compatibility with a Raspberry Pi	Compatibility with Arduino nano	Water Resistance over time	> $30
CQRobot contact water level sensor [23]	Yes	Yes	Low	$13.99
Arduino/Raspberry Pi compatible water level sensor module [24]	Yes	Yes	Moderate	$5.99

The Arduino/Raspberry Pi compatible water level sensor module, shown in Figure 3-10, fits within the project's parameters. without being expensive. Both water level sensors were compatible with the Raspberry Pi and Arduino Nano, however, the Arduino/Raspberry Pi compatible water level sensor module was significantly easier to integrate. The CQRobot contact water level sensor was the initial choice as it was designed to keep the electrical components separate from the sensor itself. However, due to its' initial integration being incredibly difficult, it was replaced with the Arduino/Raspberry Pi compatible water level sensor module.

Figure 3-10: Arduino/Raspberry Pi compatible water level sensor module [23]

Figure 3-10 depicts an Arduino/Raspberry Pi compatible water level sensor module. It displays the parts of the sensor that allow for its integration. The sensor will only be used in the collection basin as detecting the water level outside of the robot would risk damage to the Arduino and be unwanted for overall use. This sensor gives JellyBOT the capability to monitor the collection basin's water level after taking in pollutants.

3.3.5 Subsystem 5

The propeller system is crucial for the JellyBOT as it serves as the primary mechanism for propulsion and maneuverability in the aquatic environment. By utilizing propellers, the robot can generate thrust to move through the water efficiently, allowing it to navigate to different areas where trash may be located. To implement this system, a PVC pipe is used to encase the electrical and mechanical components. The components such as the ball and socket joint and other connectors or rotators within the mechanical system are 3D printed, as well as components that make the pipe watertight. In a process known as thrust vectoring, the motor attaches to one end of the PVC pipe to provide thrust and a channel for water to flow through. The yaw, pitch, and roll of the JellyBot is controlled by a system of Servo motors. To do so, metal rods attach to the moving part of the Servo motors, while the other side of the metal rod is attached to the ball and joint socket in the nozzle. This transfers the yaw, pitch, and roll motion linearly across the body of JellyBOT and into the thrust vectoring system.

Table 3-6 highlights the various options considered for the propellor used in JellyBOT based on factors such as voltage levels, horsepower, size, and price.

Table 3-7: Propeller Options

Model	Voltage	Horsepower	Size	Total price
Requirements	< 30	>300	Equilateral dimensions	< 50
XHSESA 12V-24V 20A Underwater Thruster Motor [25]	12-24 V	200 W	No	$29.98
U01 Underwater Thruster with 45A Bi-Directional ESC (Engineering Student Council) [26]	12-24 V	390 W	Yes	$39.98
DNYSYSJ Brushless Motor Underwater Thruster Motor [27]	12-24 V	200 W	Yes	$21.00

While the U01 Underwater Thruster is more costly than the other two options, it is still within budget and was chosen as the best option for JellyBOT because of its larger horsepower, which is necessary for successfully moving throughout aquatic environments that contain debris and pollutants. Equilateral dimensions are also favored because they are more suitable for attachment to the cylindrical PVC pipe. Figure 3-10 shows the propellor that JellyBOT uses.

Figure 3-10: Underwater Thruster/Propeller for ROV Boat [26]

Figure 3-10 depicts the chosen propeller for the propulsion system. This propeller is designed for underwater propulsion, making it an ideal option for JellyBOT as all components used for the robot must be waterproof. The next section shows the Prototype Design of JellyBOT.

3.4. Level 2 Prototype Design

JellyBOT's Level 2 diagram depicts the final concept of how the robot will work once all the subsystems have been integrated. The robot's design includes four arms, strategically positioned to grasp, and secure plastic waste. Once the plastic is within the grasp of the arms, a trash chamber opens to receive and store the collected waste until the robot is brought in for the day. Despite JellyBOT's impressive capabilities, it is important to note that the prototype's battery life can last up to 3-4 days on a single charge. However, to maintain optimal performance and ensure uninterrupted operation, it is recommended to bring the robot in for charging after approximately 8 to 12 hours, which corresponds to a typical day shift. This approach not only helps preserve the battery life but also ensures that JellyBOT is always ready for its next cleaning mission.

3.4.1 Level 2 Diagram

The following Figure 3-11 displays the input and output of JellyBOT based on the subsystems outlined in this document.

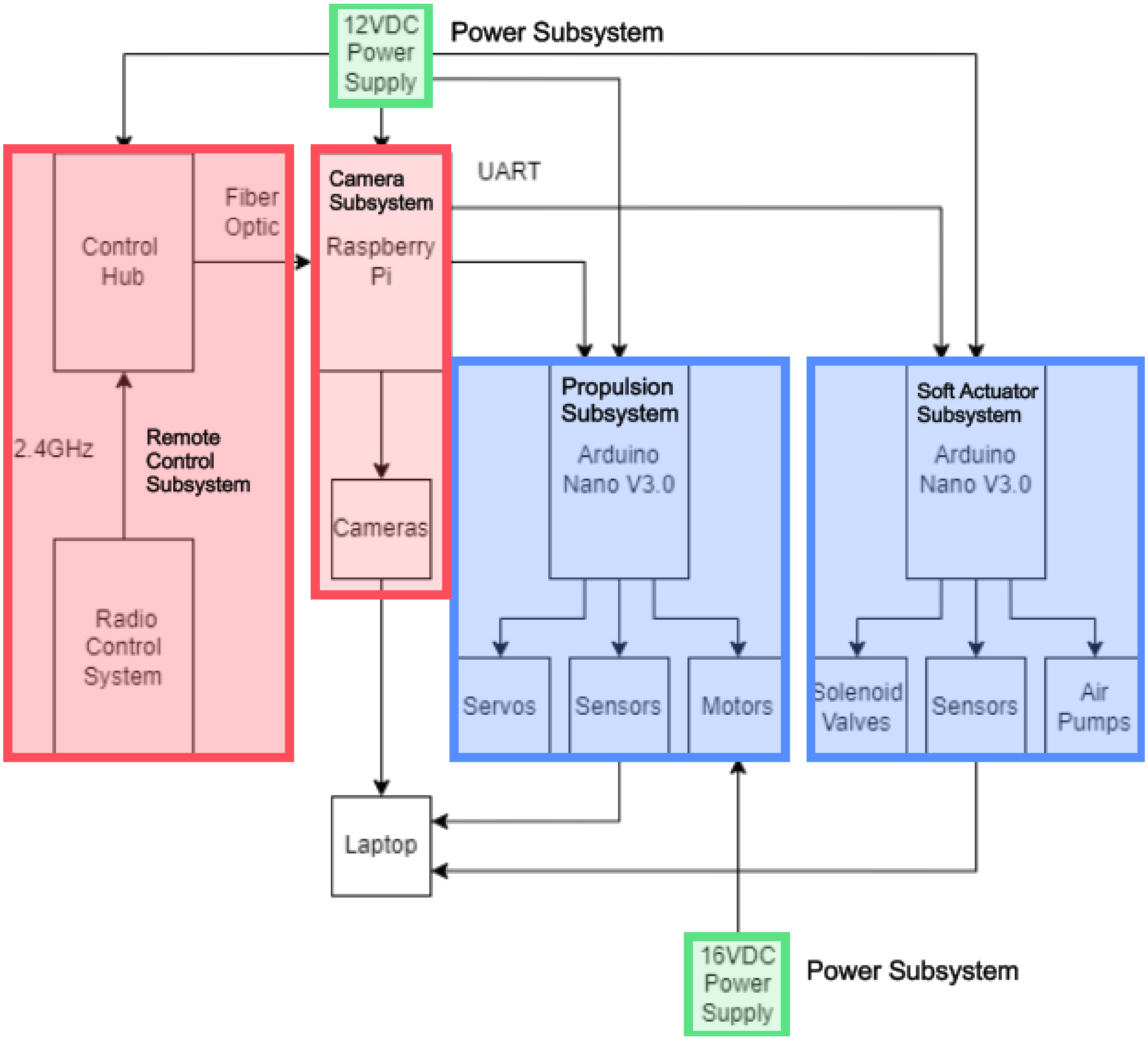

Fig. 3-11: Diagram for JellyBot (Level 2)

The provided sections detail the subsystems of JellyBOT and its approach to product design. Each part explains the functionality of the subsystems, the components used, their connections, and how these choices align with the product's goals. The Remote-Control subsystem consists of a Flysky FS-i6 Remote Control that communicates with the control hub. This hub attaches to a Raspberry Pi via a fiber optic cable, allowing the Raspberry Pi to interpret video feed from a camera. Subsequently, the Raspberry Pi communicates with an Arduino using UART protocol, activating either the control system or the actuator system based on the received signals. This seamless integration facilitates precise remote control over JellyBOT's movements and functionalities.

References

[1] "Raspberry Pi RASPBERRYPI3-MODB-1GB Model B Motherboard." Amazon, www.amazon.com/dp/B01N13X8V1. Accessed: Apr. 7, 2024.

[2] "ATmega328P Module Micro-Controller." Amazon, www.amazon.com/dp/B0CM3C3FCZ. Accessed: Apr. 7, 2024.

[3] "Flysky FS-i6 6CH 2.4GHz Radio System RC Transmitter Controller with FS-iA6 Receiver," Amazon.com, https://www.amazon.com/-Transmitter-Controller-Helicopter-Quadcopter/dp/B07CWBQ2HM. (accessed March 20, 2024).

[4] "Flysky FS-i4 4CH 2.4GHz Radio System RC Transmitter Controller with FS-iA4 Receiver," Amazon.com, https://www.amazon.com/Flysky-2-4GHz-Transmitter-Helicopter-Receiver/dp/B01916OA6I. (accessed March 20, 2024).

[5] "ELEGOO UNO R3 Project Most Complete Starter Kit w/Tutorial Compatible with Arduino IDE (63 Items)," Amazon.com, https://www.amazon.com/dp/B07FPF2HQR. (accessed March 20, 2024).

[6] "DEERC Remote Control Car High-Speed RC Racing Cars 20 KM/H, 2.4 GHZ Fast Toy Car for Kids, 2 Rechargeable Batteries for 60 Min Play, Toy Gifts for Boys Girls, Indoor Outdoor Games." Amazon.com, https://www.amazon.com/dp/B09PV8C3D3. (accessed March 20, 2024).

[7] "McMaster-Carr. High-Strength High-Temperature Thread 0.014" Diameter. [Online]. Available: https://www.mcmaster.com/8800K41/. Accessed: Apr. 7, 2024."

[8] "Micro Air Pump Electric Instrument." Amazon, www.amazon.com/dp/B0BF5XPXZY. Accessed: Apr. 7, 2024.

[9] "Mini Solenoid Valve." Amazon, www.amazon.com/dp/B0CFMY62SN. Accessed: Apr. 7, 2024.

[10] "Vicmile 3.7V 800mAh Li-ion Rechargeable Battery," Amazon.com, https://www.amazon.com/VICMILE-Battery-Chargers-Rechargeable-Compatible/dp/B09K7HVCVW. (accessed Apr. 6, 2024)

[11] "EEMB Lithium Polymer 3.7V 2000mAh Rechargeable Battery," Amazon.com, https://www.amazon.com/EEMB-2000mAh-Battery-Rechargeable-Connector/dp/B08214DJLJ/ref=asc_df_B08214DJLJ. (accessed Apr. 6, 2024)

[12] "Energizer – Max 30,000mah 3-Port Power Bank w/ LCD Screen," Bestbuy.com, https://www.bestbuy.com/site/energizer-max-30000mah-15w-usb-c-3-port-universal-portable-battery-charger-power-bank-w-lcd-screen-for-smartphones-accessories-black/649884. (accessed Apr. 26, 2024)

[13] "Gikfun Qi Wireless Charger PCBA Circuit Board Coil," Amazon.com, https://www.amazon.com/Gikfun-Wireless-Charger-Circuit-Charging/dp/B073W7P5T8. (accessed Apr. 6, 2024)

[14] "ASHATA DIY Qi Wireless Charging Receiver Module," Amazon.com, https://www.amazon.com/ASHATA-Wireless-Charging-Receiver-Ultra-Thin/dp/B07X59Z8MH. (accessed Apr. 6, 2024)

[15] “Acxico Wireless Charger Receiver Module PBCA Board Coil,” Amazon.com, https://www.amazon.com/Acxico-Wireless-Charger-Receiver-Universal/dp/B08RDMRZL5. (accessed Apr. 6, 2024)

[16] “ACEIRMC Boost Converter Polymer Lithium Battery Charging Protection Board,” Amazon.com, https://www.amazon.com/ACEIRMC-Converter-Step-Up-Charging-Protection/dp/B0C3R3TRG5. (accessed Apr. 6, 2024)

[17] “HiLetgo Fast Charging USB Charging Converter,” Amazon.com, https://www.amazon.com/HiLetgo-Module-6V-32V12V24V-Charging-Converter/dp/B07KWVL77T. (accessed Apr. 6, 2024)

[18] “Treedic Type-C Battery Charger Board with LED Indicator,” Amazon.com, https://www.amazon.com/Treedix-Protection-Adjustable-Power-Down-Regulation/dp/B09FJJBLQ1. (accessed Apr. 6, 2024)

[19] “Fish Detection Camera, Ice Fishing Camera Underwater, Visual Fishing Camera, Suitable for Providing Clear Visual Effects,” Amazon.com, https://www.amazon.com/MUNEFE-Detection-Underwater-Suitable-Providing/dp/B0CTQVZZHL. (accessed Apr. 6, 2024)

[20] “Webcam Internal Camera Board Laptop Notebook Module Replacement for 2560P 846,” Amazon.com, https://www.walmart.com/ip/Webcam-Internal-Camera-Board-Laptop-Notebook-Module-Replacement-for-2560P-846/5349994457. (accessed Apr. 6, 2024)

[21] “Arducam 5MP Camera for Raspberry Pi, 1080P HD OV5647 Camera Module V1 for Pi5, Pi 4, Raspberry Pi 3, 3B+, and Other A/B Series,” Amazon.com, https://www.amazon.com/Arducam-Megapixels-Sensor-OV5647-Raspberry/dp/B012V1HEP4. (accessed Apr. 6, 2024)

[22] “Arducam Multi Camera Adapter Module V2.2 for Raspberry Pi 5, 4B, Compatible with Raspberry Pi Camera Module 3/V2/V1, and 12MP IMX477 Cameras,” Amazon.com, https://www.amazon.com/Arducam-Camera-Adapter-Raspberry-Cameras/dp/B07TYL36MC. (accessed Apr. 6, 2024)

[23] “Ocean: Contact Water/Liquid Level Sensor Compatible with Raspberry Pi/Arduino for Automatic Irrigation Systems, Aquariums, Plants, in The Garden, in Agriculture etc.,” Amazon.com,https://www.amazon.com/CQRobot-Consumption-Resistance-Temperature-Properties/dp/B07ZMGW3QJ/ref=sr_1_2?crid=L19Z05DQVA7H&dib=eyJ2IjoiMSJ9.91Gnm_-YX3kUbFWRyUd99CEU4H3cjbZ06SftPM7bPUoId-s6dZbxsSXueJYseXFiHRy6ajPpo7aYvOCaWvZyeZ40GY2vIuzkubWy3PkQ3vxibQBLhaYGCl1w2XvXShnwOqTJI9q8U2kTkPcFeG3R5Q_QosRsG6ILrNFWPM8RDzfhv4vpZW6TFAFpV6TblBEK5VgKheXeqHu17OhMgnqeXpKWCTa6nhHNpRe9rAuxJYSWdCu-r9KzgQfpyxLpmjg7NqTKzteSVcgsB1LZl7ZefsqCQCGAMgL3SNP_1xuyVtc.5ALjXFPXg2pSR37G5Y7P5PNgQSLZ84RxzfMFZ5qPZMU&dib_tag=se&keywords=arduino+water+level+sensor&qid=1712532446&s=industrial&sprefix=arduino+water+level+sensor+%2Cindustrial%2C125&sr=1-2. (accessed Apr. 6, 2024)

[24] “Water Level Sensor Module 2PCS Rain Water Level Liquid Surface Height Depth Detection Sensor Module for Arduino/ Raspberry Pi,” Amazon.com, https://www.amazon.com/DGZZI-Surface-Detection-Arduino-Raspberry/dp/B08C7L7GBK/ref=sr_1_13?dib=eyJ2IjoiMSJ9.yIT416c4kLXdQLTHp03Eu1svIEX4cEnA

_v11ELozZPtKcJMws5mr9UFKt0WIMVukqDCKFJMJBC8OhTXdYMai3-3Or9AAKcsn7wITLIOYIYhi3xM27QJF6ty_uj-yjKXJWKhQRVVQgZJMy0c4kjfiXuhT-Z6RwKMmlbvi8SKP2okGM4TCV0VibHUTNX-JxPXG3jgSrf9VuI43woqlVlLsUrhLMNOQySp5n2VKYS5YUYc.kLNROFUV29U3ye4mLIeI5qm0X9Nf0Ncuup7Z84K65uY&dib_tag=se&keywords=arduino+water+level+sensor&qid=1713401805&sr=8-13. (accessed Apr 6, 2024)

[25] "Underwater Thruster with 45A Bi-Directional ESC,12V~16V 2Kg Thrust Brushless Underwater Subsea Thruster/Propeller for ROV Boat（CCW)," Amazon.com, https://www.amazon.com/ApisQueen-Underwater-Bi-Directional-Brushless-Propeller/dp/B0C9JR5Y5Y. (accessed Apr. 7, 2024)

[26] "U01 Underwater Thruster with 45A Bi-Directional ESC (Engineering Student Council)," Amazon.com, https://www.amazon.com/ApisQueen-Underwater-Bi-Directional-Brushless-Propeller/dp/B0C9JR5Y5Y/ref=asc_df_B0C9JR5Y5Y/?tag=hyprod-20&linkCode=df0&hvadid=659769453111&hvpos=&hvnetw=g&hvrand=4924813341247302535&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9014027&hvtargid=pla-2196673900703&psc=1&mcid=dd19a2b06f39362980829206d2894896.(accessed Apr. 7, 2024)

[27] **"**DNYSYSJ Brushless Motor Underwater Thruster Motor," Amazon.com, https://www.amazon.com/DNYSYSJ-Brushless-Underwater-Thruster-Propeller/dp/B0B3J4CM9H/ref=asc_df_B0B3J4CM9H/?tag=hyprod-20&linkCode=df0&hvadid=658799155614&hvpos=&hvnetw=g&hvrand=12053827525599199140&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9014027&hvtargid=pla-2119500758567&mcid=8e2a61de32ea3b2e87f0f4b48f845188&th=1. (accessed Apr. 7, 2024)

[28] "Design of a Qi Wireless Charging Device A Guide to Engineering Considerations." Pchintl.com, https://www.pchintl.com/wp-content/uploads/2021/04/PCH-Wireless-Charging-Device.pdf.(accessed Apr. 28, 2024)