C.E.L.P. GARDENS

SMART PLANT MONITORING

Prepared for:

Mr. Dennis Hite

EE494

10 February, 2023

Prepared by:

Cole Moore

Eric Messer

Luke Barber

Philip Entrekin

Table of Contents

Design Problem

Problem Statement

The aim of C.E.L.P. Gardens is to revolutionize the way people care for their plants by providing an inexpensive, autonomous solution. With the use of various sensors, the system will measure and gather data on the key factors that impact the health of plants, including ambient humidity, temperature, and soil moisture. This data can then be accessed in real-time through a desktop application, allowing users to easily monitor the conditions of their plants and make any necessary adjustments to keep them healthy and thriving.

One of the unique features of C.E.L.P. Gardens is its self-watering system. This system ensures that plants receive the right amount of water at the right time, reducing the risk of over-watering or under-watering, which can be a common issue for inexperienced gardeners. The self-watering system is also designed to save water and resources while maintaining optimal plant health.

In addition to the self-watering system, the C.E.L.P. Gardens system will provide notifications when the humidity, temperature, or moisture fall outside of the desired range. These notifications serve as a reminder for users to make any necessary adjustments to the conditions of their plants, helping to ensure that they remain healthy and thriving.

The overall goal of the C.E.L.P. Gardens project is to make plant care as effortless and convenient as possible. The system is designed to be easy to use and understand, making it an ideal solution for novice gardeners who may not have a lot of experience with plant care. With C.E.L.P. Gardens, anyone can have a green thumb and enjoy the benefits of a thriving indoor or outdoor garden.

ABET Justification

The C.E.L.P. Gardens project meets ABET criteria for an engineering design problem as it requires the application of various engineering disciplines such as electrical, computer, and software engineering to solve a real-world problem. The project involves the design and development of a device that can accurately measure humidity, soil moisture, and temperature levels and then transmit that data wirelessly to the user's device. This requires the integration of numerous components, such as sensors, a self-watering system, and a power management system. The project also requires the use of wireless communication technologies, software development, and power management techniques. Currently, there exists only piecemeal solutions to this problem, but we aim to provide a standalone product that can complete the goal on its own and without routine maintenance/intervention necessary at a price point that would be appealing to the intended customer.

Design Overview

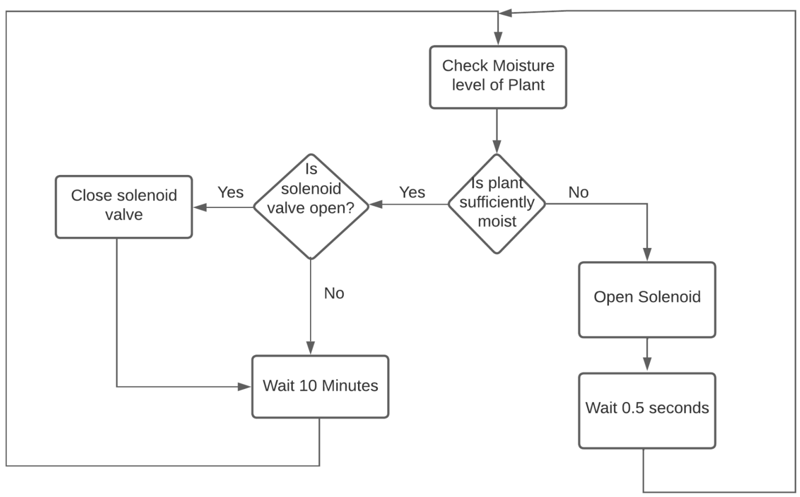
The C.E.L.P. Gardens project is designed to offer an inexpensive and hands-free solution for plant care, providing real-time data on humidity, moisture, and temperature, as well as a self-watering system. The device features a capacitive sensor for measuring soil moisture, a temperature sensor for monitoring ambient heat, and a humidity sensor, providing a comprehensive view of the conditions surrounding the plant.

One of the key features of the C.E.L.P. Gardens project is the automatic water delivery system and reservoir tank, which is capable of sustaining plants for at least a week without requiring manual intervention. The water delivery system is triggered by the soil moisture sensor, ensuring that the plants receive the right amount of water at the right time, keeping them healthy and thriving.

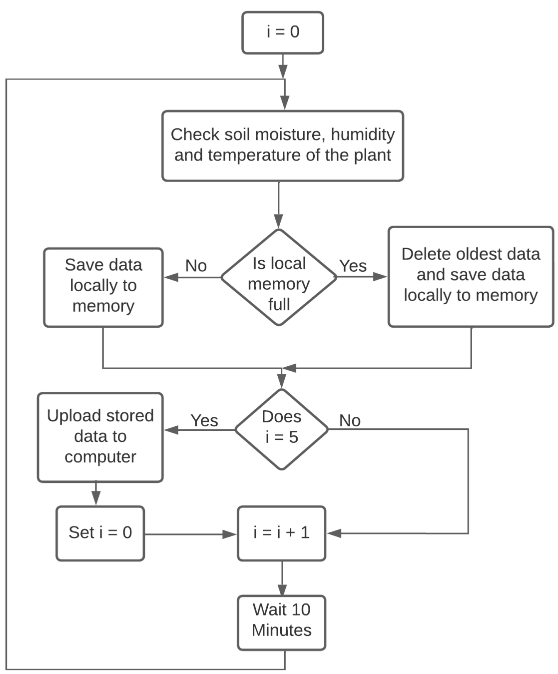
The device is equipped with Bluetooth connectivity, enabling wireless data transmission to a desktop application. The user can access the data from their computer, providing a convenient way to monitor the conditions of their plants and make any necessary adjustments. The Bluetooth connectivity also enables the device to receive firmware updates and new features, making it a flexible and adaptable solution for plant care.

Device Algorithms

Hardware Feedback System



Software Logic Loop



Scope Definition

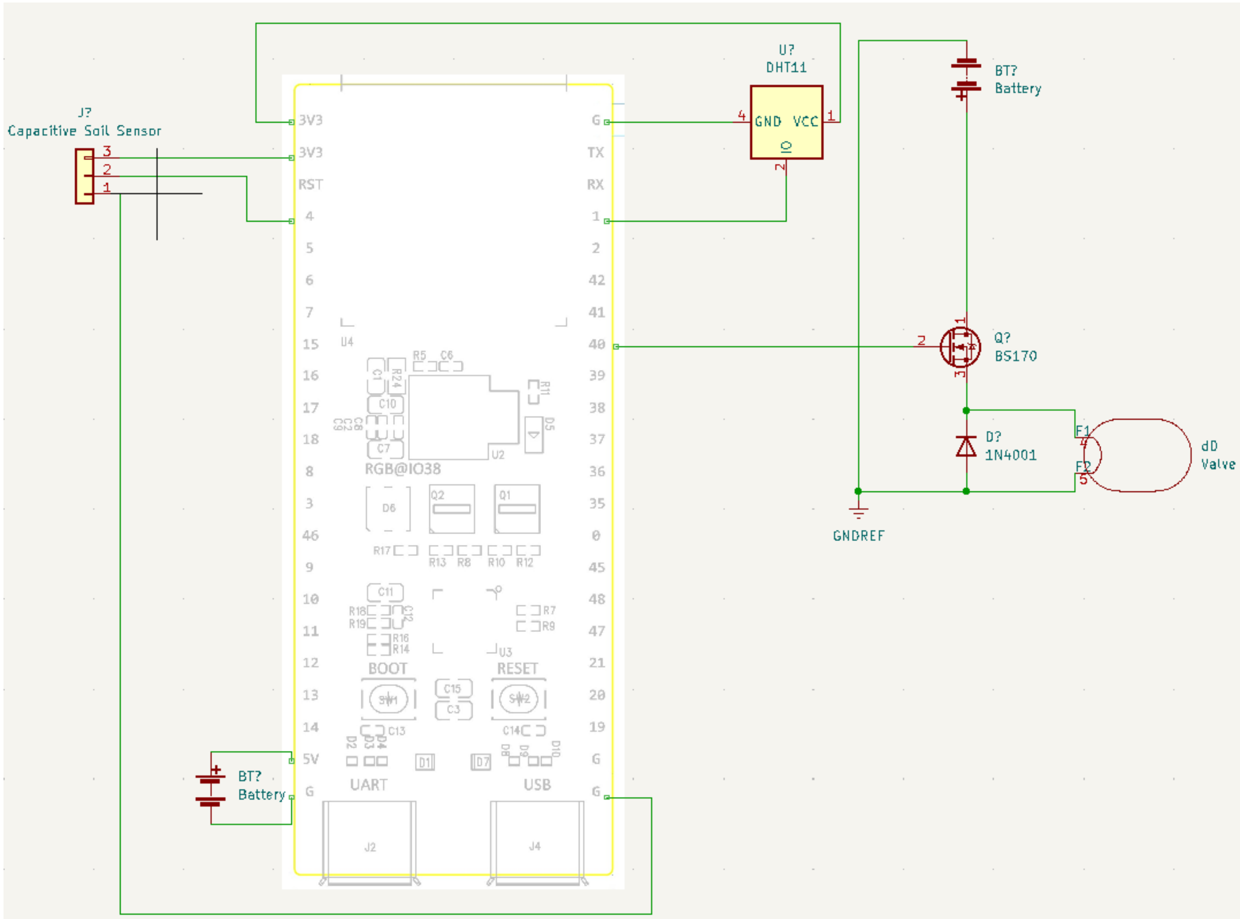
Objectives

The C.E.L.P. Gardens module will provide real-time data on soil moisture and temp./humidity levels for a small potted house plant. In addition, it should feature a self-watering system capable of keeping sufficient water levels for the plant without human intervention. Furthermore, it should store and transmit recorded data to a GUI desktop/mobile application. It should also operate independently of a wired power source - use a battery for a set amount of time. Finally, it should be functional for different size plant containers.

Specifications

Hardware Components

Microcontroller: ESP32-S3-DevKitC-1 v1.1
Temp./Humidity Sensor: DHT11
Moisture Sensor: B07SYBSHGX
Diode: COM-08589
Voltage Regulator: L7805CV
MOSFET: BS170
Solenoid Valve: Adafruit-997
Device Case: B07W9H8M3Z
Power Solution: 2x 9V Batteries



Dimensions

Height: 190.50 mm

Width: 70 mm

Depth: 28 mm

Weight: Less than 5 lbs

IP Rating: IP 53

Operating Temperature: 1℃ - 45℃

Power

Controller Input Voltage: 3.3V - 6.5V

Operating Current: 128mA

Solenoid Input Voltage: 6V - 9V

Operating Current: 160 mA - 240 mA

Battery Voltage: 9V

Battery Capacity Each: 550 mAh

Communication & Storage

Bluetooth Technology: BLE 5 - 2.4 Ghz

Bluetooth Range: 20 Meters

Data Storage Capacity: 8 MB Flash memory

Moisture Sensor Range: 514 Points

Relative Humidity Repeatability: ±1%

Relative Humidity Accuracy: At 25℃ ±5%

Temperature Repeatability: ±0.2℃,

Temperature Accuracy: At 25℃ ±2℃

Software Applications

Sensor Data Handling: C++

GUI: Python

Constraints

Design Budget

The budget must be kept low such as to provide a reasonable price to the customer, who is likely to be unwilling to spend more than $60-$70 for this kind of product. In order to maintain a healthy profit margin, the design's cost must be kept below $50. It is important to keep in mind that the product would be sold in high volumes, so the profit margin can remain slim for an individual unit.

Manufacturability

The product would likely be sold in high volumes, as it is small, inexpensive, and only accounts for one plant per unit, so some customers may have a need for more than one. Thus, quick and efficient manufacturing would be necessary to maintain supply. To achieve this, we are designing the device in such a way that the components can be easily assembled with no need for proprietary tools.

Aesthetics

The C.E.L.P. Gardens module would be used most commonly in homes, so maintaining a sleek, inline appearance will be vital to appeal to the customer. In order to achieve this, we will design the body such that it can stick into the soil itself, not compromising the silhouette of the pot.

Legal

The C.E.L.P. Gardens module must be unique enough to not violate copyright/patent law in the U.S., where it would be distributed. Thus, we have added an automatic watering system which will adequately protect us from any claims of stolen intellectual property.

Sustainability

It will be necessary for the device to maintain operation autonomously without human intervention for an extended period of time, as this is an important quality that sets it apart from existing patents/ideas/solutions. We intend to design a product that can operate on its own for at least 7 days. The electronic components feature non-corrodible pins, and the capacitive soil moisture sensor will be sufficiently waterproofed to keep the device functional indefinitely.

Patent and Market Research

United States Patent #US9271454B1

Abstract: An intelligent gardening system and method for monitoring and analyzing a moisture level in individual gardening pots and/or containers is provided. A system comprises a moisture measuring sensor integrated into a pot/container. A gardener can read moisture-related data using a mobile device, a computer, or a tablet, or directly from a built-in display. The gardener can send the moisture level-related data along with other data (such as, a type of a plant, a soil type, size of a pot, a plant size, location, current weather, an air temperature, etc.) to a central server connected to a central gardening database or to a cloud service and receive gardening recommendations. The gardening recommendations can include other recommendations pertaining to a particular plant and gardening conditions.

This patent is similar to our project, but it is missing some facets of the design. The C.E.L.P. Gardens module will include a self-watering system that will rely on the data provided by the moisture sensors. Additionally, it would provide alerts to a device wirelessly when conditions are outside of acceptable limits. This patent also doesn't explicitly state how long the device would run for autonomously, and we intend to rigorously test our product for long-term operation without human intervention.

United States Patent #US6357179B1

Abstract: A self-watering planter having a container and a floor structure . The latter includes one or more troughs that extend downwardly from the floor . When manufacture of the planter is complete, a chamber portion for receiving planting medium is

> provided above the floor. This chamber portion includes interior regions of the troughs. A lower chamber portion is provided beneath the floor structure for receiving water. Openings in bottom ends of troughs permit water in the lower chamber portion to be wicked up into the planting medium in the troughs, which in turn is wicked up into planting medium in upper portions of the upper chamber portion. The planter is designed to be manufactured with a single mold in a single molding operation.

This patent is similar to our idea for a self-watering system, but it fails to include the integration of sensor data with wireless transmission or any kind of notification system/GUI.

Verification and Validation

Progress Reports & Team Meetings

Weekly Progress Reports

Weekly Progress Report: #1

26 January, 2023

Work Completed:

The team has discussed design and hardware specifications for the C.E.L.P. Gardens module. We have decided to go for a "backpack" style module to sit on the lip of the plant pot to use for support. Also, the hardware team has researched possible components/software to use for the module.

Work in Progress:

The team is working on the Project Proposal presentation to be completed by 2/10/23. We will have decided by then how the self-watering system of the module will work. Along with this, other features of the system are being researched as possible candidates to be added to the system, such as a pH sensor or LED screen. The choice of power is also up for discussion, with the addition of new components, more power may be necessary. The initial choice was 4 AA batteries, but a 9V battery may be the final choice. All parts of the project need to be ordered soon to begin assembly.

Challenges and Changes:

One challenge the group is still facing is how the watering system will operate. There comes sacrifices with either choice of using gravity with a valve or using a pump for watering. The choice of using gravity will provide a low-power, simple solution but come with a larger water tank to sit on the pot. This could cause the pot to tip over if it is not capable of supporting the entire C.E.L.P. Gardens module with a small water tank, about the size of an 8oz bottle. The other choice for watering is using a pump. The pump will allow for an easier tank location but will have more power draw than the gravity watering option.

Weekly Progress Report: #2

2 February, 2023

Work Completed:

The team has furthermore discussed design and hardware specifications for the module. The team has assigned individual slide responsibilities for each member for the proposal presentation. The hardware team has confirmed parts for the design list such as the moisture sensor and casing.

Work in Progress:

Most of or all of the hardware list will be finalized by the proposal presentation. The development board should be the last decision to be made for the hardware. The team is working to finish the proposal presentation by mid next-week.

Challenges and Changes:

The development board is still up for question. The final decision will be decided by the team with most of the decision coming from the hardware and software team. The choice of the development board will be based on compatibility with bluetooth/Wi-Fi modules.

Weekly Progress Report: #3

9 February, 2023

Work Completed:

The team has completed the hardware list. We have also ordered some of the hardware for the first prototype. The power problem has been decided by going with (2) 9V batteries for our system.

Work in Progress:

The team is almost done with the Written Project Proposal and Proposal presentation - we plan to finish by 2/9. We plan to finish ordering the parts by the end of this week.

Challenges and Changes

The development board changed as we needed a more inexpensive way to power our sensors and I/O configurations. The light sensor has been removed due to the team seeing it as unnecessary.

Product Testing

Bench Test

This section of testing will involve a bench test of the hardware and software components to ensure that data transmission from the sensor module to the user device is seamless end-to-end in a controlled environment. Additionally, it will be important to check that all aspects of the design flowchart are being executed--that the decisions made by the device are accurate.

Field Test

The field test will only come after the bench test has been completed successfully, and will involve putting the device in its intended position so it can attempt to monitor its plant host's environment and transmit relevant data and notifications. This test will also determine if the device is capable of making decisions as to when the automatic watering system should be actuated.

Runtime Test

The runtime test would come after rigorous field testing, where we have already ensured that the device works as we intended. It would be an extended test to measure the length of time that the device can autonomously run without human interference--as this is a very important quality that sets the C.E.L.P. Gardens module apart from existing patents/ideas/solutions. This test would also be used to evaluate the health of the plant as a consequence of our design.

Project Management

Primary Stakeholders

Luke Barber - Project Lead

As Project Lead, Mr. Barber will manage the design and scheduling necessary to complete the project correctly and on time. He will oversee all areas to make sure components of the project are assembled and operate according to design specifications.

Philip Entrekin - Software Lead

As the software lead for the plant sensor project, Mr. Entrekin’s main responsibilities include overseeing the development and implementation of the desktop application and wireless communication technologies used to transmit data from the sensors to the user. He will also ensure that the mobile application is user-friendly and easy to understand.

Eric Messer - Hardware Lead

As the Hardware Lead, Mr. Messer will be responsible for overseeing the design and implementation of the physical components required for the project. This includes tasks such as sourcing, assembling, and storing components.

Cole Moore - Research Lead

As Research Lead, Mr. Moore will organize any research data pertinent to the project such as hardware component specifications and software requirements. He will also ensure that the project does not violate any existing patents and identify the nature of the differences in design between our project and any existing ideas. Additionally, he will collect and quantize any necessary market research.

Deliverables

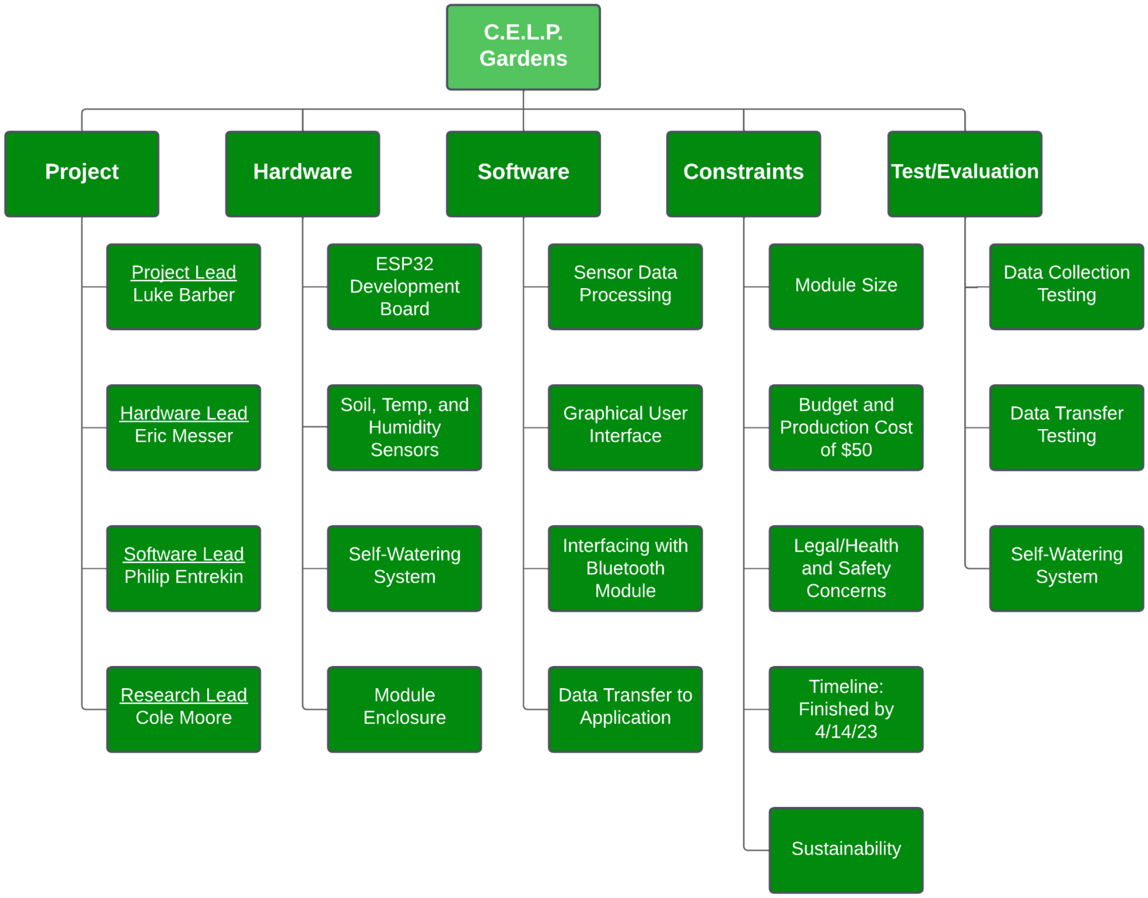
Current Completed Deliverables:

- Team Bios 1/15/23
- Project Summary 1/24/23
- Weekly Progress Report #1 1/26/23
- Weekly Progress Report #2 2/02/23
- Weekly Progress Report #3 2/09/23
- Project Proposal Presentation and Written Report 2/10/23

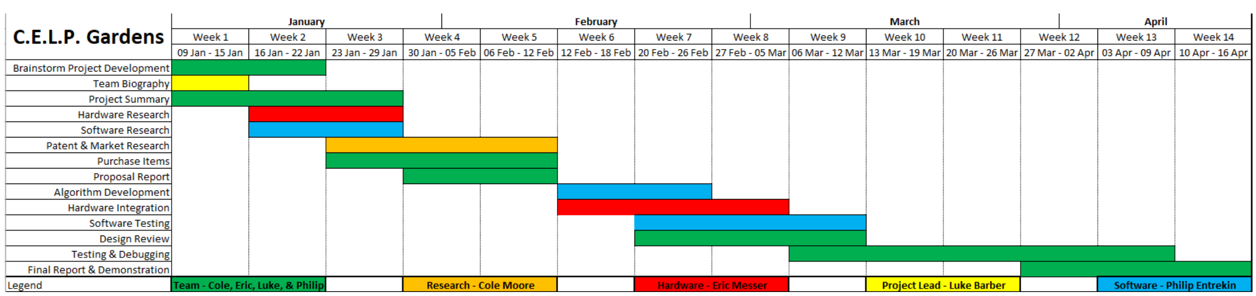
Future Deliverables:

- Weekly Progress Reports
- Design Review 3/10/23
- Written Assignment #1 & 2 3/31/23
  Final Project Report, Presentation, Poster, Demonstration, and Project Binder 4/14/23
- News Article and Reflections Report 4/14/23

Work Breakdown Structure (WBS)



Responsibility Assignment Matrix



Budget & Component Justification

Bill of Materials (BOM)

C.E.L.P. Gardens	Part Number	Part Description	Retail Price	Vendor
Hardware	ESP32-S3-DevKitC-1-N8R8	Microcontroller	$15.00	mouser.com
	DHT11	Temp./Humidity Sensor	$3.15	amazon.com
	B07SYBSHGX	Moisture Sensor	$2.00	amazon.com
	Adafruit-997	Solenoid Valve	$6.95	adafruit.com
	COM-08589	Diode	$0.25	mouser.com
	L7805CV	Voltage Regulator	$0.69	digikey.com
	BS170	MOSFET	$0.44	newark.com
	3D-Printed	Threading Adapter/Spout	$1.70	coreprototyping.xyz
	B07W9H8M3Z	Device Case	$2.20	amazon.com
	Alkaline	2x 9V Batteries	$4.84	amazon.com
Total			**$37.22**	

Component Justifications

- The ESP32 is less expensive than the Arduino Nano, and has more flash memory (8Mb), so we chose it as our microcontroller despite both being capable of everything the device requires.

- The DHT11 was chosen as our Temp./Humidity Sensor because it was inexpensive, and has throughput as opposed to surface mounted, which fits our needs better than other options.

- The B07SYBSHGX moisture sensor was chosen because it is capacitive rather than reactive, which means it will degrade much slower than other options.

- The watering solution, the Adafruit-997 solenoid valve, was chosen because it requires little voltage and is exceptionally inexpensive compared to other options such as pumps.

- The power solution, 2x 9V batteries, were chosen because of size and voltage requirements.