**Design**

**Key Features**

ACAMP’s ability to effectively monitor and control the environment is due to several key features. First and foremost is the structure that houses our project. The dimensions of the frame are 27 x 43 x 78 inches and it is made out of redwood. Additionally, the structure stands on 2 inch wheels that allow the otherwise heavy structure to be moved with relative ease, putting the total height at 80 inches. These dimensions were chosen such that the structure is small enough to fit through smaller-than-average doorways but large enough to comfortably house a 25 x 25 inch grow tray. The inside of the structure will be coated with a material called “panda plastic” - a type of plastic that is black on the outside with a reflective sheet of white inside. The white side of the panda plastic allows for between 75-90% light reflectivity, allowing for greater light absorption by the plants.

In order to maximize plant growth, the project intends to automate the light and water cycles of the plants to the user’s specifications. The growth environment will be monitored using a sensor that measures for temperature and humidity. Using the values from these sensors, fans and dehumidifiers can be controlled to match the desired parameters. In addition to environmental control, the water being fed to the plant too will be monitored using pH and total dissolved solids (TDS) sensors. Using solenoid valves, pH solutions and nutrients can be released to ensure that the water in the reservoir is ideal. An additional feature is plant height detection using a webcam. After the webcam determines the height of the plants, the light will be raised or lowered to stay a constant distance away from the top of the plants to ensure ideal growth conditions.

One of the most notable features of our project is the ability to monitor and control the growth environment online using a custom web UI. From this interface, the user will be able to set the parameters of their environment: light duration and height, the number of water cycles and duration, temperature, humidity, pH, and TDS. The values read from the sensors will be recorded so the history of the growth cycle can be viewed. Furthermore, the user will be able to view their growth environment via the webcam. We believe that this level of digital interaction truly sets our project apart.

**Components**

**Physical Structure**

The goals of our project demand a controlled environment that works to aid the hydroponic growth process. This means our physical design must face several considerations. The structure must be strong enough to hold the water reservoir and grow table, in addition to supporting the light suspension system. We are using redwood to build this structure because we believe that it is a strong wood capable of handling the weight of the project. The wood will be treated with a water resistant stain to better control humidity. Lastly, our structure will have a shelf near the top of the structure where the most of the control electronics will be stored.

We will be insulating the room using panda plastic, which prevents outside light from entering while preserving the artificial light. In comparison to mylar sheeting for light reflectivity, panda plastic produces less hot spots in environments, making the panda plastic a more suitable insulator for our project. We have yet to decide on how to fully insulate the environment from the outside, but we have discussed using fiberglass between two layers of wood paneling.

**Data Management Systems**

Since our project requires the ability to communicate with the user over the Internet, we needed to pick a communication interface that could connect via Ethernet. After discussing with several graduate students who were working on developing an Ethernet port for a microcontroller, we determined that we needed a pre-built Ethernet connection. For this, we chose the Raspberry Pi. The Raspberry Pi has a built in Ethernet port, 2 USB ports, 17 GPIO pins, and can be written using the Python programming language. So far, it has been remarkably easy to connect to the Internet using the Raspberry Pi. When deciding on a microcontroller, we took into account several factors:

* At least 256k Flash memory as we expect our project to process a lot of data
* At least 4 UARTs to connect; one to connect to the Raspberry Pi, and at least 3 for sensors
* Ample GPIO
* Good online support for unforeseen obstacles

Using these criteria, we determined that the Atmel ATMega2560 was the best microcontroller for our needs. The specifications of the microcontroller match the required amount of Flash, UARTs, and GPIO. Additionally, Atmel has a strong online community that has proven itself to be an invaluable resource. For our development board, we decided to use the Arduino Mega 2560 which we write to using SPI from Atmel Studio 6. One benefit of using this board is that we are able to use the USB port using serial communication with the Raspberry Pi. For all of the aforementioned reasons, the ATMega2560 has been a good choice as our microcontroller.

**Sensors**

Our project requires that we are constantly monitoring the environment. Four different parameters will be measured: pH, TDS, temperature, and humidity. We will be measuring pH using the aptly named “pH Kit” made by Atlas Scientific. This sensor can detect pH levels from 0.01 to 14.00 and comes with a chip that communicates with the microcontroller via USART. The sensor only needs to be calibrated about once a year and can be run continuously without affecting accuracy. Due to the ease of communication and very low maintenance requirements, we picked this particular pH sensor. After working with Atlas Scientific’s pH sensor, we decided to also use their “Conductivity Kit” as it functions largely the same as the pH sensor while decreasing debugging time spent on other sensors. This sensor can give us three different values: electrical conductivity (µs), total dissolved solids (KCl), and salinity (pss). By parsing this data, we can provide the user with a wealth of data pertaining to the water quality.

To measure both temperature and humidity, we are using the DHT22 temperature/humidity sensor made by Aosong Electronics. The temperature is measured in Celsius with two decimal places for added resolution; the humidity sensor has the same resolution and is a humidity percentage measurement. We picked this sensor because it is accurate and reliable as a long-term sensor. Additionally, there are several libraries already written by the distributor, Adafruit Industries, that communicates directly with the Raspberry Pi.

We plan on using a photo diode to determine whether or not the light in the room is on. Information from this sensor can be used to tell the user if their light bulb is no longer working. Lastly, we plan on using a webcam to determine the height of the plant. The Raspberry Pi will take the image from the webcam and compare the current image of the plant to previous images to determine the change in plant height. From this, we will know how much to adjust the height of our light.

**Actuators**

In order to control the environment, we must make use of several actuators that adjust various parameters of the environment. First, we needed a water pump that can fill our grow table quickly but slow enough that it wouldn’t overflow. For this, we decided to go with EcoPlus’s ECO-264 submersible pump, which pumps water at 290 gallons per hour. The pump only has on-off states, making it easy to control, and was relatively cheap.

Next, to control the pH and TDS of the system, we will be attaching containers with solutions for each of these to solenoid valves. We are using the Ehcotech BBTF-CD-12VDC solenoid valve for several reasons. First, it has a slow flow rate which means we can distribute the solutions slow enough to ensure we don’t overshoot our intended pH and TDS concentrations. Second, it only uses two wires that don’t depend upon polarity to turn on, making it simple to use. The other side of the solenoid will be connected by a tube that goes into the water reservoir at the base of the grow table.

To adjust the temperature of the system, we intend on controlling the speed of the exhaust fan which should adequately regulate temperature. Because our room is so small, most inline exhaust fans can circulate air much faster than what we need. We have yet to figure out which fan we intend on using. The fan must have a minimum speed of 15 CFM and anything above that would be used for cooling the system.

In order to adjust the height of the light, we plan on using a winch and pulley system powered by a servo motor. Once the height of the plant is determined, the servo should either raise or lower the light hood. We plan on having the light ballast separate from the light hood so that there will be less weight that this system has to hold.

The last actuator we intend on using is a dehumidifier. We haven’t decided upon a dehumidifier yet but our main design concerns are size and cost. The reservoir of whatever dehumidifier we purchase will be connected back into the main water reservoir for the growth tray, so we do not need a very large dehumidifier. Instead, we need to ensure there is enough space for it in the system, so we need a dehumidifier that is strong enough to handle the humidity of our system but small enough to fit comfortably.

**Peripherals**

The success of this project relies on several other components not directly linked to the control structures. To begin with, we will be oxygenating the main water reservoir with the EcoPlus ECO-AIR-1 air pump. This air pump was chosen as it was recommended by Santa Cruz Hydroponics to work well with our water pump. Next, we plan on using the ATX power supply to provide the power for our project. The ATX power supply is capable of supporting three different DC voltages: 3, 5 and 12 volts. Additionally, the power supply’s current ratings are more than capable of handling the load we intend on using. To power the light, we plan on using a digital ballast that is capable of supporting both high pressure sodium and metal-halide lights. Lastly, we plan on installing an oscillating fan near the middle of the structure. The oscillating fan strengthens the stems of plants by recreating the wind. For this, we just need a cheap 12V oscillating fan that doesn’t blow too fast, which can damage the plants.

**Division of Labor**

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| --- | --- | --- |
| **Name** | **Lead** | **Assisting In** |
| Justin Johnson | * Physical Design * Gannt Chart * PCB Design * Web Design | * Solidworks |
| Daniel Gunny | * Temperature/Humidity sensor * Exhaust Fan * Dehumidifier * Power Supply | * pH/TDS sensors |
| Wayland He | * Solidworks Design * Webcam Image Processing * Co-Lead Light Adjustment System | * Code Supervision |
| Stark Pister | * pH/TDS sensors * Solenoid Release Valves * Co-Lead Light Adjustment System * Code Supervision | * Web Design |