Environmental Analyzer Pod

"An accessible environmental sensing module to provide contextual data for outdoor researchers and citizen scientists."

Team Basically Wizards

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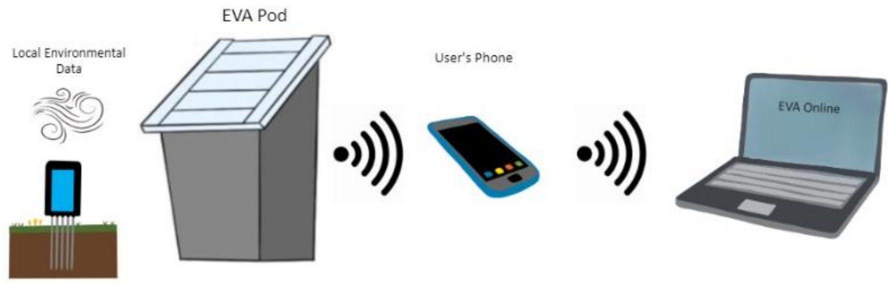
Sponsored by NASA Colorado Space Grant Consortium

7.3 Project summary

7.3.3 Elevator pitch

The NASA EVA Pod is designed to autonomously collect environmental data over several weeks, providing comprehensive background information. This data is then used with data from the NASA STELLA Module, a hand-held device used to capture key environmental measurements during field visits, allowing for detailed data comparison and comprehensive analysis of the environment.



7.3.4 A use case

A high school class is looking to run a half-semester-long project about characterizing the environment of a region in their state. The students are only expected to understand how to navigate to the website the data will eventually be transmitted to. The EVA Pod will arrive [pre-assembled] with a charger and data cable. Once charged, the class will designate a specific name for the sensor that will allow it to be researchable on the website.

Once the product is charged and labeled, the team can create a unique stand or attachment device for their desired deployment location. The Pod itself will be weatherproof but designed to be mounted at a specific orientation. Once ready to start collecting data, users can hold down a designated button for 5 seconds. The EVA Pod will begin collecting data (confirmed by 2 LED blinks). The Pod will run on its low power consumption (and solar power generation) design until it begins to transmit data to a connected device or until the button is held down for another 5 seconds to turn it off. If the button is held for 20 seconds, all locally collected data will be deleted (confirmed by 3 LED blinks).

Then the team will open the website which stores the data and will choose to upload new data. If in a field site with no cell service, the user may need to download data while at the sensor pod to their phone and then upload it to the site later. The user downloads the data by connecting their phone and then pushing the button on the device. This sends a CSV file of the stored data to their phone. They may then clear the hub's local data storage if desired. (The device uses the phone's GPS to get its latitude and longitude for the recent set of data, so it may be moved and restarted if necessary.) When they are able to, the class then navigates to the website and selects the file to upload. After the data is collected and uploaded, it can be analyzed from the classroom or in the field. If the class desires, they can utilize the Stella handheld modules to collect data by hand at the site and compare it with ease to the data collected by the pod.

7.3.5 Product features

Minimum 2-week battery life, allowing users to gather environmental data in remote areas under study without needing to physically be there while the EVA pod autonomously runs.

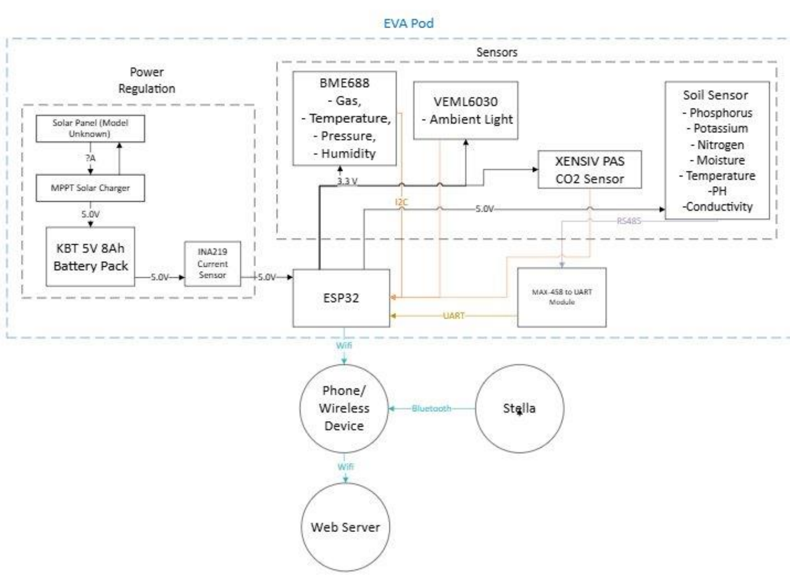
Data can be compared to spectrometry data from NASA STELLA, meaning it is time-stamped, geotagged, and in like units, to allow users to use both products in tandem to gain a full contextualization of the environment.

The EVA Pod is low cost, which maximizes accessibility and allows students and citizen scientists to benefit from it.

Weatherproof enclosure, giving the user confidence that it will survive the elements and keeping safety of the environment as the top priority.

Easy to set up and easy to use, so that anyone can purchase an EVA Pod and use it to collect data, without any specialized knowledge necessary.

7.3.6 Product System Architecture



Main functional elements are the sensors, the ESP23, the power regulation block, a user device, a NASA STELLA (optional), and the web server.

The beating heart at the center of the device is the ESP32. The sensors interface with the ESP32, which transmits readable data into a file which can be uploaded to a web server via the user device. The web server can also integrate NASA STELLA data that has been uploaded via the user device. The Power Regulation Block only interfaces with the ESP32 and the sensors.

7.3.7 Coolness

Our product features the integration of a multitude of sensors while consuming very little power, being low-cost, and small. These sensors enable citizen scientists to create their own studies and experiments that need a large overview of their environment's key characteristics.

7.3.8 Non-commodity Technology included

Sensors:

- NPKHCTH-S (7-in-1 Soil Sensor)
  - Selected due to sensors for Nitrogen, Phosphorus, Potassium, Soil Moisture, Temperature, Humidity, and PH.
- BME 688
  - Selected due to including sensors for gas, temperature, pressure, and humidity. Also selected due to low-power consumption.
- VEML 6030
  - Selected due to sensing ambient light and low-power consumption.

Microcontroller:

- ESP32S3-P
  - Selected for Wi-Fi capabilities for easy upload, flash memory to store 2 weeks of data, I2C and UART to communicate with sensors, and familiarity.
- RS485 Module
  - Converts soil sensor outputs to UART compatible output

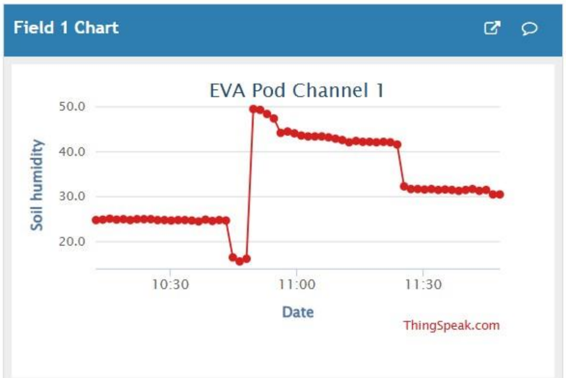
API:

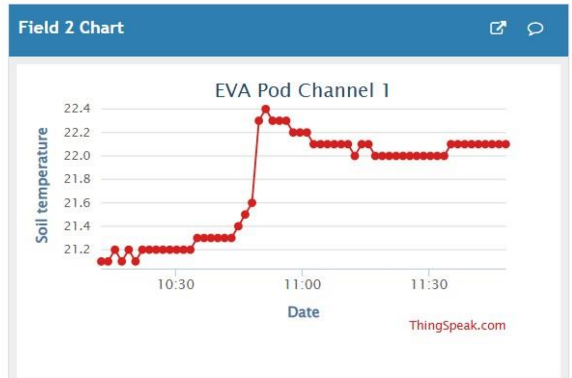
- Google Maps
  - Selected due to high customizability and familiarity with the anticipated customer base.

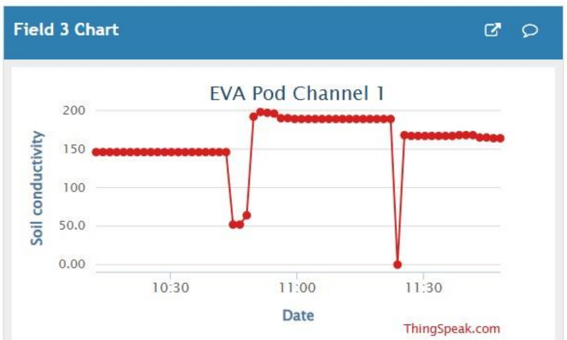
Technology Option	Maturity Risk	Complexity Risk
NPHKTHC-7 in 1 soil sensor	Low, commercially established technology	Medium, RS485 Protocol may be confusing
BME-688 temp humidity sensor	Low, commercially established technology	Low, already established working code
VEML-6030 Light sensor	Low, commercially established technology	Low, already established working code
MAX-485 RS485 to UART	Low, commercially established technology	Medium, Unknown area and sending commands over UART may be confusing
ESP32-S3 Pico	Low, commercially established technology	Medium Low, previously used in capstone class

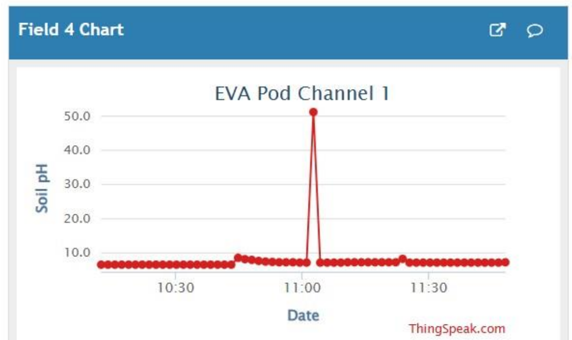
7.3.9 Phase 1 prototype

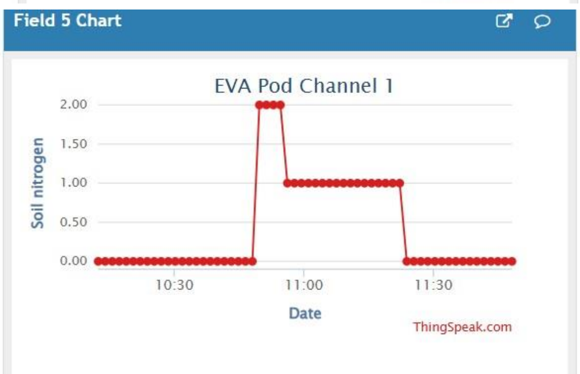
It demonstrated the ability of the product to continuously report accurate environmental data to the IOT ThingSpeak server. It also demonstrated the need for us to actually implement the code needed to send our sensors into sleep mode in order for us to hit our power goals.

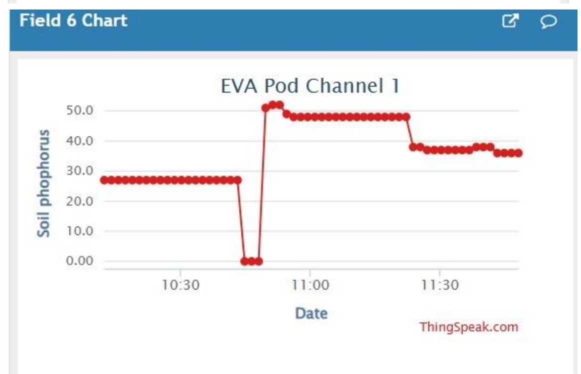

Field 1 Chart
EVA Pod Channel 1
Soil humidity
50.0
40.0
30.0
20.0
10:30
11:00
11:30
Date
ThingSpeak.com


Field 2 Chart
EVA Pod Channel 1
Soil temperature
22.4
22.2
22.0
21.8
21.6
21.4
21.2
10:30
11:00
11:30
Date
ThingSpeak.com

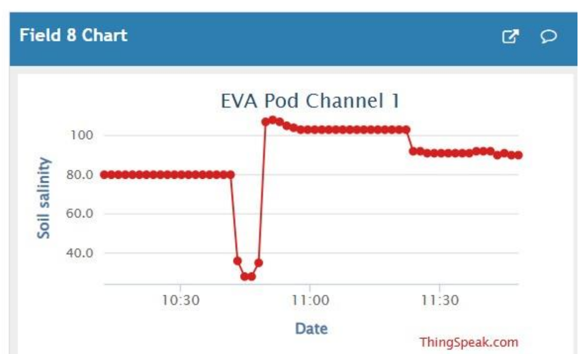

Field 3 Chart
EVA Pod Channel 1
Soil conductivity
200
150
100
50.0
0.00
10:30
11:00
11:30
Date
ThingSpeak.com


Field 4 Chart
EVA Pod Channel 1
Soil pH
50.0
40.0
30.0
20.0
10.0
10:30
11:00
11:30
Date
ThingSpeak.com


Field 5 Chart
EVA Pod Channel 1
Soil nitrogen
2.00
1.50
1.00
0.50
0.00
10:30
11:00
11:30
Date
ThingSpeak.com


Field 6 Chart
EVA Pod Channel 1
Soil phophorus
50.0
40.0
30.0
20.0
10.0
0.00
10:30
11:00
11:30
Date
ThingSpeak.com


Field 7 Chart
EVA Pod Channel 1
Soil potassium
40.0
30.0
20.0
10.0
0.00
10:30
11:00
11:30
Date
ThingSpeak.com


Field 8 Chart
EVA Pod Channel 1
Soil salinity
100
80.0
60.0
40.0
10:30
11:00
11:30
Date
ThingSpeak.com

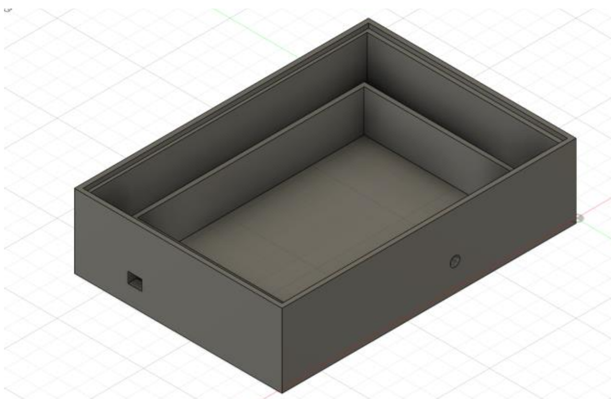
ThingSpeak Charts

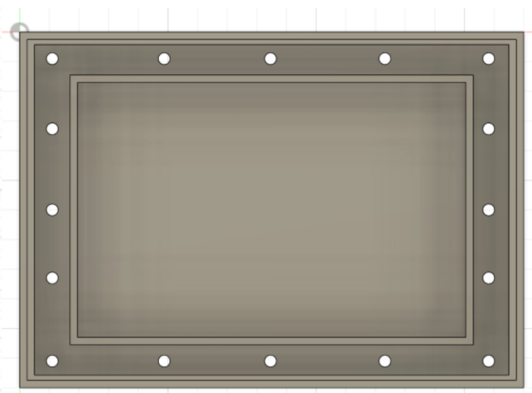
Below are some of the risks that kept us up at night, and the prototype helped highlight some areas that we were correct to be concerned about. The soil sensor is presenting some issues involving accuracy, and the power did not last the entire week, let alone 2 weeks. The power issue is easily solved, as we just needed to enable our sensors for sleep mode. The soil sensor is going to be subject to re-evaluation, and is our largest source of risk at the present time.

Risk	Phase 1 Testing	Plan B
Insufficient power	Check that design operates for 2 weeks on a single battery charge	Bigger or new battery (raises cost)
Communication with Soil Sensor	Obtain readings of all 7 parameters measured by sensor using MAX485	Use a different soil sensor, such as Adafruit's (descopes project, less parameters measured)
Enclosure not waterproof enough for extreme weather	Test enclosure for weatherproofing by spraying water from a nozzle for 5 and 10 minutes, then test functionality.	Explore alternative waterproofing techniques such as chemical coatings.
Unit cost < $300	Calculate total cost of phase 1 prototype and estimate final unit cost	Descope project
Utilizing JavaScript for Google Maps API	Create 1 location pin and upload EVA Pod data into at least 1 graph	Remove map interface and move to drop down menus of data
Inaccurate sensors	Compare data taken by EVA pod with data taken by known, accurate sensors	Explore alternative sensors or recommend EVA calibration

Risk Chart

Pictures:





Challenges encountered

Enclosure: Originally, we wanted to have a waterproof rating of IPx6, but throughout development we realized that to have the circulation we needed for the sensors to be useful, the most we could do is “weather proofing”. We also had some original design issues with the Integrated Teaching and Learning Laboratory 3D printers (bed adhesion and general failure of the prints), but that was resolved after a small modification of the CAD design and switching to the Capstone Bambu printers.

Soil Sensor: The soil sensor which we were originally drawn towards for its ability to measure Nitrogen, Potassium, and Phosphorus has been determined to only indirectly measure these values through the conductivity of the soil, which gives unreliable measurements. Thus, we are moving to measuring the off gassing of the soil and using other heating-based sensors to calculate different chemicals within the soil.

7.3.10 Tests results

With our phase 1 design, we have informally verified communication and data output from each sensor, nonvolatility of data storage, and successful short-range wifi connection to user devices from the ESP32. For our demonstration, we chose to test the power draw and accuracy of a selection of our sensors. We are not at a point at which we can officially test the enclosure or the final unit cost, but these are lower risks.

For our power test, we found that the EVA Pod only lasted 3 days before dying, while taking measurements at 4-hour intervals and uploading to Thingspeak each time. We had expected at least 1 week. We hypothesized that this was due to the power draw while sleeping, not taking measurements or connecting to Wi-Fi, because we had previously witnessed it last 24 hours without dying while measuring at <2-minute intervals. We confirmed this suspicion in the lab by measuring the current draw of the system during each of its 3 states. Compared to the values we expected from the datasheets, we found that the current draw during measurement was lower, during Wi-Fi transmission was about the same, and during sleep was factors greater. This led us to discover that although we were calling esp_deep_sleep_start(), all of the sensors were still on, so we will fix this in the code.

EVA Pod state	Expected current	Measured current
Sleep	24 uA	44 mA
Measure	140 mA	55 mA
Host wifi server	130 mA	160 mA

We additionally tested sensor accuracy, and found that our air quality (temperature, humidity, pressure) agrees with a commercial QingPing air quality sensor and is thus acceptable. We also tested the soil nutrient measurements against a chemical test kit. We expected these to be inaccurate as we have learned that they are derived and have seen them change with conductivity. We have decided that this soil sensor is unacceptable, and we will transition to using a cheaper sensor for soil temperature, moisture, and pH, and designing an off-gassing soil module for calculating nutrient contents.

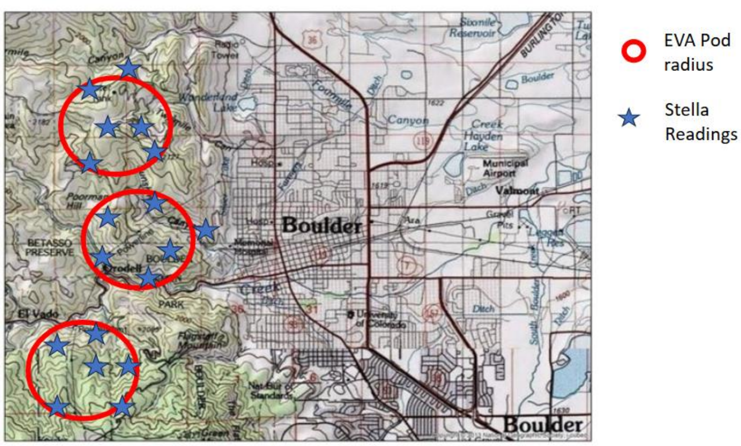
Parameter	Comparison Measurement	Expected Range	Observed	Agreement?
Temperature (degrees Celsius)	24.9	21.2 - 28.6	26.6	Yes
Relative humidity (%)	20.2	17.2 - 23.2	18.2	Yes
pH	7	6 - 8	5.8	No
Nitrogen (mg/L)	5	2.5 - 7.5	1	No

Phosphorus (mg/L)	80	40 - 120	48	No
Potassium (mg/L)	240	120 - 360	41	No

7.4 The next steps

The future of our design is currently uncertain given the unreliability of the NPK component of our soil sensor. To provide a more distinct and accurate characterization of soil quality we will be examining soil off gassing using the MQ series of gas sensors in combination with a co2 sensor. We will measure methane (MQ-4 and MQ-9), hydrogen (MQ-8), a combination of sulfur, benzine and ammonia (MQ-135), carbon monoxide (MQ-7B and MQ-9), and liquid petroleum gas (MQ-9). These readings can be used in conjunction with the pH probe on our soil sensor to determine which gases are responsible for certain sensors that have overlapping coverage reading high. The whole system will give detailed soil off gassing profile that can be used to characterize overall plant health. In combination with the other environmental analysis features previously implemented we will be able to provide data that STELLA alone cannot provide. In addition, our plans for next semester include the following:

- We will be designing a web interface for the EVA and STELLA data and utilizing the Google Maps API. This is a large addition to the Mini-Expo prototype as it will be the polished interface for users to be able to not only upload EVA Pod data, but also visually compare it to STELLA data.



- The final product will look considerably more compact than the current iteration and will likely have a second module added to it for the new soil sensor. We will move everything to custom PCBs instead of the solderless breadboard.

The largest risks present are the foreseeable struggles of working with JavaScript (as it is an unfamiliar language for the team), and the exploration of new possibilities for our soil sensor component. Our plan is to utilize contacts and consult with those more familiar with the topics to advise when needed.

Product Development Document

EVA (Environmental Variance Analyzer)

Team Basically Wizards (A3)

Julia DiTomas

Anika Mathur

Shane McCammon

Sydney Medina

Andrew Morris

Eli Wall

Sponsored by NASA Colorado Space Grant Consortium

Revision dates:

9/26

10/3

10/10

12/5

Managerial Roles and Descriptions

a. Budget manager & Logistics manager (finance) - planning out the major purchases and balancing the budget and responsible for procuring all the parts, materials and doing all the purchasing: Anika
b. Communications manager: responsible for the quality of all the presentations and written content related to your project: Julia
c. Project schedule manager, responsible for keeping track of the project timeline and rolling action item list: Sydney/Andrew
d. Coordination Manager responsible for facilitating team meetings/bonding: Andrew
e. Assignments scheduling/documents manager: making sure all assignments are completed and submitted on canvas on time: Shane
f. Technical lead: Responsible for the overall technical details of the project. Responsible for risk management and ensuring that the appropriate actions take place, breakdown of work: Eli
g. Customer manager: responsible for managing the relationship and communications with the customer. Usually leads customer meetings: Sydney

Technical Roles and Descriptions

h. PCB design lead, which includes design using the EDA tool, selecting components, submitting PCB orders, circuit design, assembly, testing, debug: Shane/Anika
i. Analog circuit design and ace debug expert: Andrew/Sydney/Shane
j. Embedded systems engineering (firmware development): Eli
k. User interface designer: Julia/Andrew
l. System architect (overall system design, including hardware and software): Shane/Eli
m. Software engineering (other than firmware): Eli/Julia
n. Rf design or principles, related to any rf signaling, communications: Julia
o. Test engineering: developing a test plan, executing it and interpreting the results: Shane/Andrew/Sydney
p. Hardware and enclosure designer: Anika/Sydney/Eli

Administrative Roles Summary

Team Member	Lead Roles	Supporting Roles
Julia	Communications	
Andrew	Coordination	Project Schedule
Anika	Budget/Funding	
Shane	Assignments Scheduling	
Sydney	Customer, Project schedule	
Eli	Technical Lead	

Technical Roles Summary

Team Member	Lead Roles	Supporting Roles

Julia	RF, User interface	Software
Andrew	Analog circuit	User interface, testing
Anika	Hardware/enclosure	PCB
Shane	PCB, system architect	Analog circuit, testing
Sydney	Testing	Analog circuit, hardware/enclosure
Eli	Software, embedded systems	System architect, hardware/enclosure

Product Definition

The Environmental Variance Analyzer (EVA) gives citizen scientists a deeper understanding about the local environment and climate. The EVA Pod is an accessible, battery-powered, user-friendly outdoor module that records data such as temperature, humidity, air pressure, and soil moisture autonomously. This data is then uploaded to an online database and displayed on the EVA website accessible to the public. The EVA Pod's data will be integrated with the data from NASA's STELLA, a DIY handheld environmental sensor for students, and Landsat imagery, to provide a complete picture of a region's environmental health.

The STELLA users lack the environmental data to contextualize their STELLA spectrometry readings and are thus limited in the conclusions that they can draw about the health of the area under study. The EVA Pod will grant them easy access to the relevant data needed, allowing them to analyze the immediate environment on a measurement-by-measurement basis as well as view changes over space and time on the website.

Our intended users are mainly high school and college students involved with the STELLA program, but additionally amateur nature/hiking clubs, citizen scientists, or any community members interested in a science project about local climate. The product senses local weather and environmental phenomena so that regions can be characterized and analyzed over time. This can be helpful for agricultural practices, climate change research, and STEM education. The EVA Pod can be left outdoors in the area of interest for weeks on end (due to low power system and local power generation) collecting and storing data, which can then be uploaded to the user's phone or computer and posted to the website.

Critical Capabilities and Behaviors:

- Run on a low-power mode to maximize lifespan and provide at least 2 weeks of autonomous operation on a single battery charge.
- Detect and record climate data and store that data locally.
- Interface directly with the user's device to allow data download without need for cell service or internet.
- Provide a website for storing and publicly sharing data and allow users to look at data over a map and over time.

Use Cases

Use case 1:

A high school class is looking to run a half-semester-long project about characterizing the environment of a region in their state. The students are only expected to understand how to navigate to the website the data will eventually be transmitted to. The EVA Pod will arrive [pre-assembled] with a charger and data cable. Once charged, the class will designate a specific name for the sensor that will allow it to be researchable on the website.

Once the product is charged and labeled, the team can create a unique stand or attachment device for their desired deployment location. The Pod itself will be weatherproof but designed to be mounted at at specific orientation. Once ready to start collecting data, users can hold down a designated button for 5 seconds. The EVA Pod will begin collecting data (confirmed by 2 LED blinks). The Pod will run on its low power consumption (and solar power generation) design until it begins to transmit data to a connected device or until the button is held down for another 5 seconds to turn it off. If the button is held for 20 seconds, all locally collected data will be deleted (confirmed by 3 LED blinks).

Then the team will open the website which stores the data and will choose to upload new data. If in a field site with no cell service, the user may need to download data while at the sensor pod to their phone and then upload it to the site later. The user downloads the data by connecting their phone and then pushing the button on the device. This sends a CSV file of the stored data to their phone. They may then clear the hub's local data storage if desired. (The device uses the phone's GPS to get its latitude and longitude for the recent set of data, so it may be moved and restarted if necessary.) When they are able to, the class then navigates to the website and selects the file to upload. After the data is collected and uploaded, it can be analyzed from the classroom or in the field. If the class desires, they can utilize the Stella handheld modules to collect data by hand at the site and compare it with ease to the data collected by the pod.

Use case 2:

Nathan, and a group of his friends enjoy hiking and watching the development of plants over the course of the seasons. After doing this for a couple springs cataloging photos and descriptions, Nathan decided to purchase a STELLA so he and his friends could get some actual measurements. However, after using the STELLA a few times, he realized that he couldn't really tell how well they are developing without some information about the local environment.

To fix this, Nathan decided to buy STELLA's companion product, the EVA Pod, and after receiving it prebuilt, following the simple setup guide online. He fully charges the batteries, and connects it to the EVA Pod Website. He hikes it out to where he usually uses his STELLA, and pushes the soil probe into the ground, mounting the EVA Pod to a nearby tree with the strap it comes with. After pressing its start button and checking that it's on and reading data by looking at a visual indicator, Nathan hikes back home.

Every 2 weeks he or a friend goes out to the EVA Pod, and replaces its batteries, making sure to download all of the data from the last two weeks onto their phone, over Bluetooth. After taking this home, and uploading it to the EVA Pod website, they can use the data they have gathered from their STELLA, and the data from the EVA Pod, to keep track of the life cycle and health of the plants, as well as watching how environmental changes influence the plants growth and development over time.

Marketing Requirements

Number	Marketing Requirement	Importance	Notes for testing
1	Compact: Approximately trail cam sized	Medium	Compare dimensions to that of a popular trail cam
2	Low Cost	High	Calculate total cost of components and enclosure

3	Easy integration with cell phone	High	Be able to transmit data from the pod to a cell phone
4	Ease of Use: Can be used with minimal technical experience	Low	Utilize a focus group from SWE to test complexity of use
5	Able to operate unattended and safely for long periods of time via battery and/or solar power generation	High	Test to see if the created module lasts the required amount of time. (If we add solar power, test power generation as well)
6	Collect data to characterize environment	High	View collected data for all environmental parameters in file format
7	Provide confirmation of operation with user	Medium	Utilize an LED to signal when wifi is on
8	Written documentation and use instructions for non-technical audience	High	Give to high school team and ask to set up

Engineering Requirements

Marketing Requirement #	Engineering Requirement #	Description of Requirement	Justifications	Test Procedure
6	1	Geotagged data with phone GPS interface	Essential for locating data measurements on map	View lat/long data in file
6	2	Sensor: Temperature ± 2°C	Essential for classifying an environment	View data in a file or on website for temp
6	3	Sensor: Ambient Light ± 5 Lux	Essential for classifying an environment	View data in a file or on website for light
6	4	Sensor: Humidity ± 2%	Essential for classifying an environment	View data in a file or on website for humidity
6	5	Sensor: Air pressure ± 10 feet altitude	Essential for classifying an environment	View air pressure data in file or on website
6	6	Sensor: CO2 ± 10 ppm	Essential for classifying an environment	View data in a file or on website for CO2
6	7	Sensor: NPKPHCTH-S for measuring soil moisture, pH, nitrogen, phosphorus, conductivity, temperature, and potassium	Essential for classifying an environment	Saturate soil with substances and test against chemical soil test kit
5	8	Weatherproof	Must be able to withstand reasonable precipitation	Splash water on enclosure and check for vulnerabilities
5	9	Low Energy Timer Integration (<75uA operation)	Must be able to exist in the field for two weeks	Measure current consumption over one full measurement cycle
5	10	Solar Power Generation. 1.5A charge rate. Output no more than 4.4V	Must be able to exist in the field for weeks	Measure watts per hour generated for the device
3,4,8	11	Wifi connection to phone/laptop, 5 m range	Need to transmit data to website	Ensure data is transmitted effectively, and that it can be stored without service/internet
3,4	12	Can be set up by non-engineers	Accessible to any interested citizen scientist	Focus group test with written documentation
5	13	Charging port to battery between 0.5C and 1C (capacity)	Must have initial power. Rechargeable things are preferable	Ensure that the charging port is durable, fully

				charge, discharge, recharge using this.
5	14	Nonvolatile Data Storage	Must retain locally stored data when at low battery or no battery.	Store data in solid state memory, and power cycle the device.
2	15	< $300 per unit, but lower is ideal	Low cost increases overall sales and increases accessibility.	Total cost of module is less than $300
7	16	LED on when wifi server hosted, off otherwise	Signal to user state of device for troubleshooting	Check that the LED is on when in the wifi server state, and off when sleeping or measuring
1	17	Smaller than 4”x6”x8”	Must be compact to easily carry to sites and mount	Measure dimensions

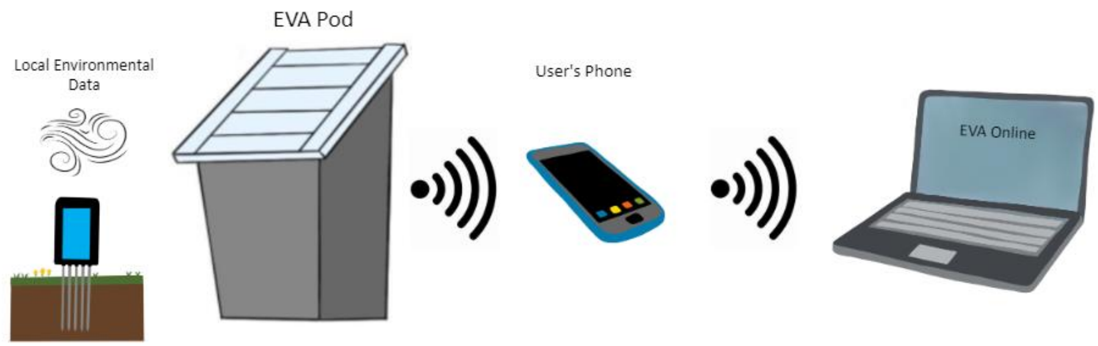
Design Constraints

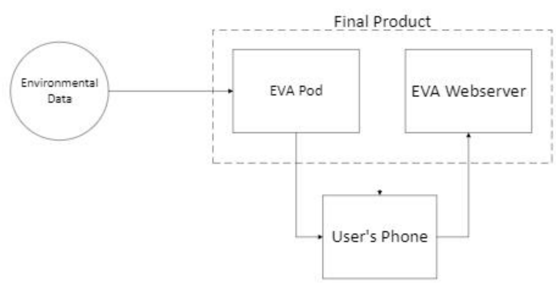
- **Cost must be below $300 per unit**
- **Data must be timestamped and geotagged to integrate with Stella data**
- **Trail cam size or smaller**
- **Design must be intuitive for customers**
- **Must measure air temperature**
- **Must measure local relative humidity**
- **Must be capable of transferring data to an external database**
    - **EVA Pod must connect to user device**
    - **Website must accept upload from user**
- **Must be rechargeable**
    - **Wired charging (must)**
    - **Solar/wind/etc (optional stretch goal)**
- **Must indicate low power and problems with data transfer to user**
- **Must withstand average weather conditions with minimal external wear, and no internal damage**
- **Must Measure Battery Health and have protective fuse to protect against battery explosion in the woods.**
    - **Waterproof**
    - **Windproof**
    - **Fully enclosed**

Product Design and Technology Selection

Team Basically Wizards

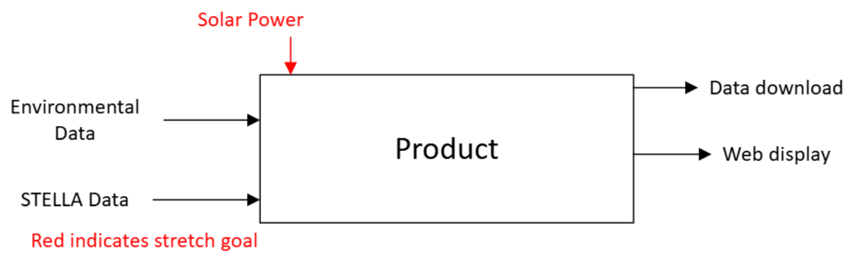
Functional Block Diagram:





Functional Decomposition:

Level 0:



	Environmental Variance Analyzer
Inputs	Environmental Data: Local air and soil measurements taken by EVA Pod. See Environmental Data Specification for more details. STELLA Data: Spectroscopic and environmental data taken by the NASA STELLA instrument Solar Power: Power generated by sunlight
Outputs	Web Display: User-friendly website displaying the data taken from a given EVA Pod and STELLA for a selected date Data download: Data taken from a given EVA Pod and STELLA for a selected date in csv format.
Functionality	The product consists of the physical EVA Pod, which measures environmental parameters at some outdoor site of interest and sends it to the user's phone or computer, and the user interface, which allows the user to upload, view, share, and download their EVA and STELLA data.

Environmental Data Specification:

Soil Conductivity: Local measurement of conductivity of soil Soil Potassium: Local measurement of potassium content of soil Air Temperature: Local measurement of ambient air temperature Ambient Light: Local measurement of ambient light hitting EVA pod Air Pressure: Local measurement of ambient air pressure Relative Humidity: Local measurement of relative humidity of air

CO_2 Concentration: Local measurement of CO_2 concentration in air

Soil Temperature: Local measurement of temperature of soil

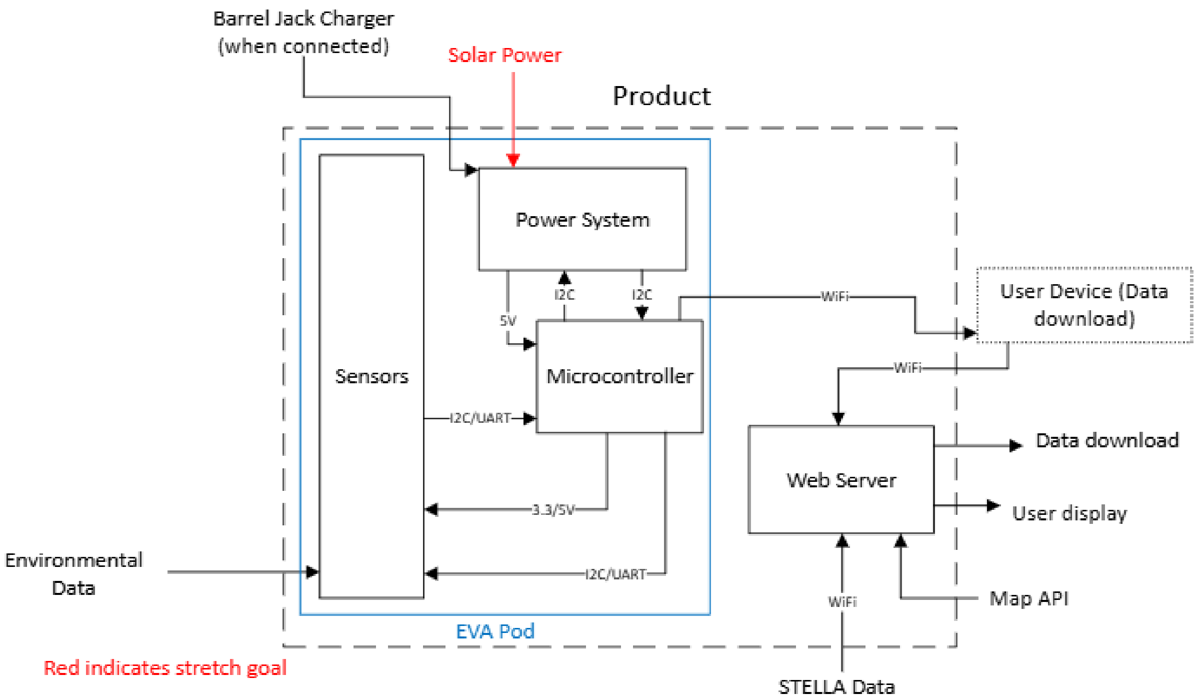
Soil Moisture: Local measurement of soil water content

Soil Nitrogen: Local measurement of nitrogen content of soil

Soil pH: Local measurement of pH of soil

Soil Phosphorus: Local measurement of phosphorus content in soil

Level 1:



Module	Web Server
Inputs (energy, information, materials)	EVA Pod Data: Enviromental data measured by EVA Pod and uploaded to web server via WiFi STELLA Data: Spectroscopic and environmental data taken by NASA STELLA and uploaded to web server via WiFi Map Data: Maps of areas with EVA Pods pulled from source such as OpenStreetMap or Google Maps through API
Outputs (energy, information, materials)	User Display: Web page with graphical display of data for selected date and EVA pod Data Download: User may select to download the data in a csv file from the web page
Functionality	The web server stores EVA/STELLA data that users upload, allows the user to select the data by location on a map, displays graphs of the data, and lets the user upload data files.

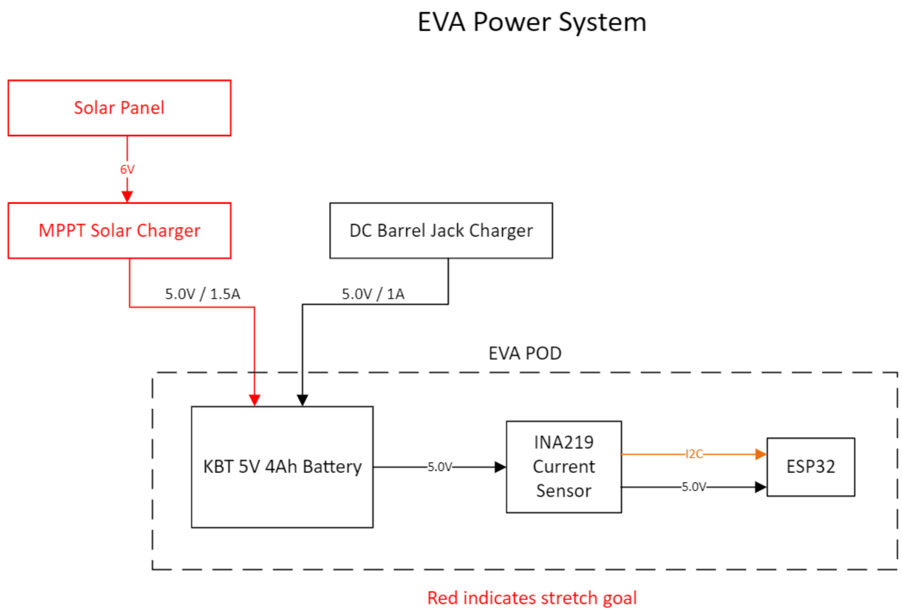
Module	Power System
Inputs (energy, information, materials)	Solar Power: Power from sunlight hitting a solar panel Code: Current sensor configurations from microcontroller via I2C Barrel Jack Charging: 5 VDC from barrel jack charger (only when connected)
Outputs (energy, information, materials)	Power: 5 VDC to power microcontroller Current Sensor Reading: Current and sensor measurements via I2C.
Functionality	The power system stores and supplies power to the EVA Pod through the microcontroller. As a stretch goal, it takes in solar power and recharges the battery for extended life.

Module	Microcontroller
Inputs (energy, information, materials)	Sensor Readings: Environmental data output from sensors via I2C or UART Power: 5 VDC from power system
Outputs (energy, information, materials)	Code: Sensor configurations via I2C or UART Power: 3.3 or 5 V to power each sensor depending on requirements Data: Environmental data averaged at specified time interval and converted to SI units, output to user device as csv file via Wifi
Functionality	The microcontroller configures the sensors, receives environmental data and performs necessary conversions/averaging, stores the data onboard, and sends a file with the stored data to the user's device using its Wifi server hosting capabilities.

Module	Sensors

Inputs (energy, information, materials)	Environmental Data: Local air and soil measurements taken by EVA Pod. See Environmental Data Specification for more details. Power: 3.3 or 5 V from microcontroller outputs, depending on specific sensor requirements Code: Sensor configurations from microcontroller via I2C or RS485 depending on the sensor
Outputs (energy, information, materials)	Sensor Readings: Environmental data output from sensors via I2C or RS485
Functionality	The sensors module periodically reads in the environmental data and sends it to the microcontroller.

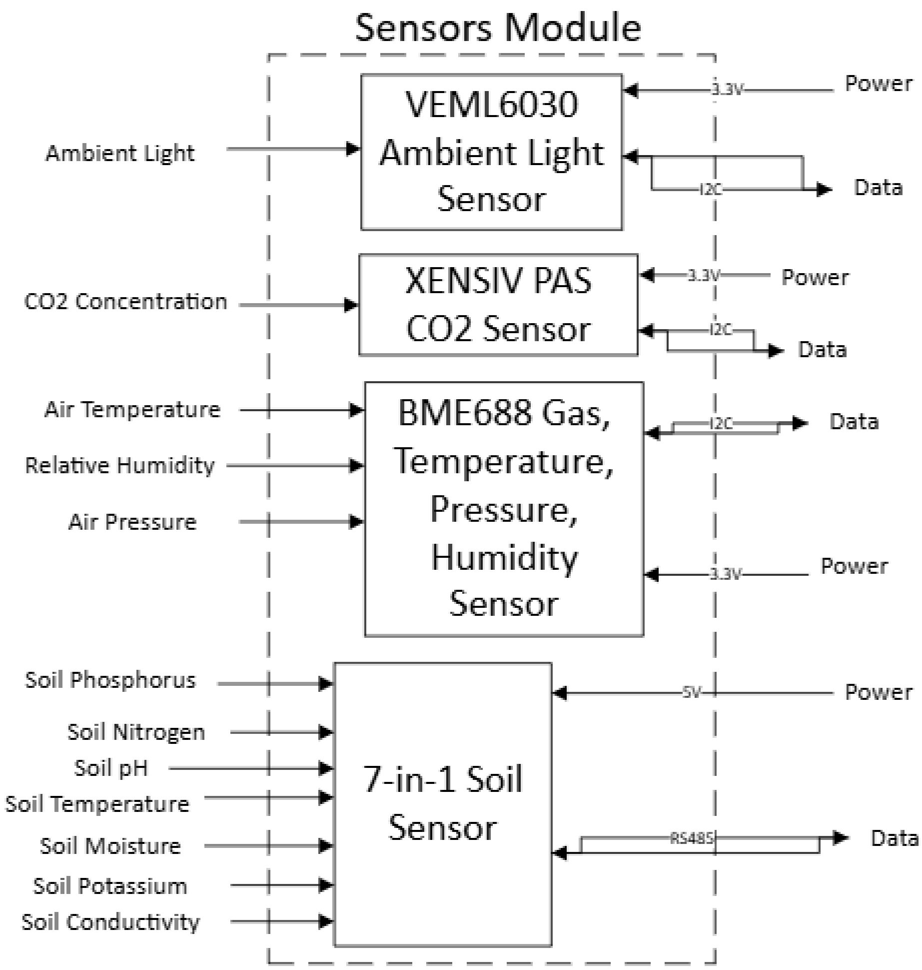
Level 2 – Power System:



Module	Power System
Inputs (energy, information, materials)	Solar Panel: 6V 3W Solar Charger: Adafruit Universal USB/DC/Solar Charger • USB Type C / DC Barrel Jack • 1.5 A charging rate • 1-10VDC Input Voltage Barrel Jack Charging: 5 VDC from barrel jack charger (only when connected)
Outputs (energy, information, materials)	Power: 5 VDC through current sensor to microcontroller
Functionality	The power system stores and supplies power to the EVA Pod through the microcontroller. As a stretch goal, it takes in solar power and recharges the battery for extended life.

Module	INA219 Current Sensor
Inputs (energy, information, materials)	Power: 5VDC from battery
Outputs (energy, information, materials)	Power: 5VDC to microcontroller
Functionality	Off the shelf sensor to monitor total current consumption

Level 2 – Sensors Module:



Component	VEML6030 Ambient Light Sensor
Inputs (energy, information, materials)	Ambient Light: Local measurement of ambient light hitting EVA pod Power: 3.3 V from microcontroller Code: Sensor configuration from microcontroller via I2C
Outputs (energy, information, materials)	Ambient Light Reading: Ambient light data via I2C
Functionality	The VEML6030 measures ambient light in lux and sends this data to the microcontroller via I2C

Component	XENSIV PAS CO2 Sensor
Inputs (energy, information, materials)	CO2 Concentration: Local measurement of CO2 concentration in air Power: 3.3 V from microcontroller

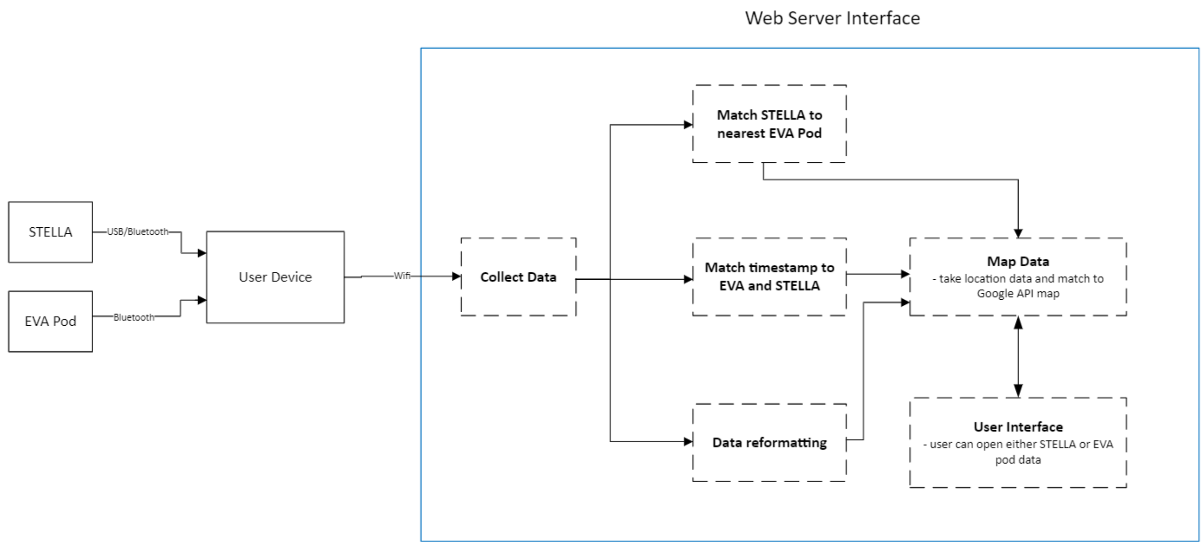
	Code: Sensor configuration from microcontroller via I2C
Outputs (energy, information, materials)	CO2 Concentration Reading: CO2 concentration data in ppm via I2C
Functionality	The XENSIV PAS CO2 sensor measures the CO2 concentration of surrounding air and sends this data to the microcontroller via I2C

Component	BME688
Inputs (energy, information, materials)	Air Temperature: Local measurement of ambient air temperature Air Pressure: Local measurement of ambient air pressure Relative Humidity: Local measurement of relative humidity of air Code: Sensor configuration from microcontroller via I2C Power: 3.3 V from microcontroller
Outputs (energy, information, materials)	Sensor Readings: Air measurements sent to microcontroller via I2C
Functionality	The BME688 measures air temperature, pressure, humidity, and CO2 concentration and sends this data to the microcontroller via I2C

Component	7-in-1 Soil Sensor
Inputs (energy, information, materials)	Soil Conductivity: Local measurement of conductivity of soil Soil Potassium: Local measurement of potassium content of soil Soil Temperature: Local measurement of temperature of soil Soil Moisture: Local measurement of soil water content Soil Nitrogen: Local measurement of nitrogen content of soil Soil pH: Local measurement of pH of soil Soil Phosphorus: Local measurement of phosphorus content in soil Power: 5 V from microcontroller Code: Sensor configuration via RS485

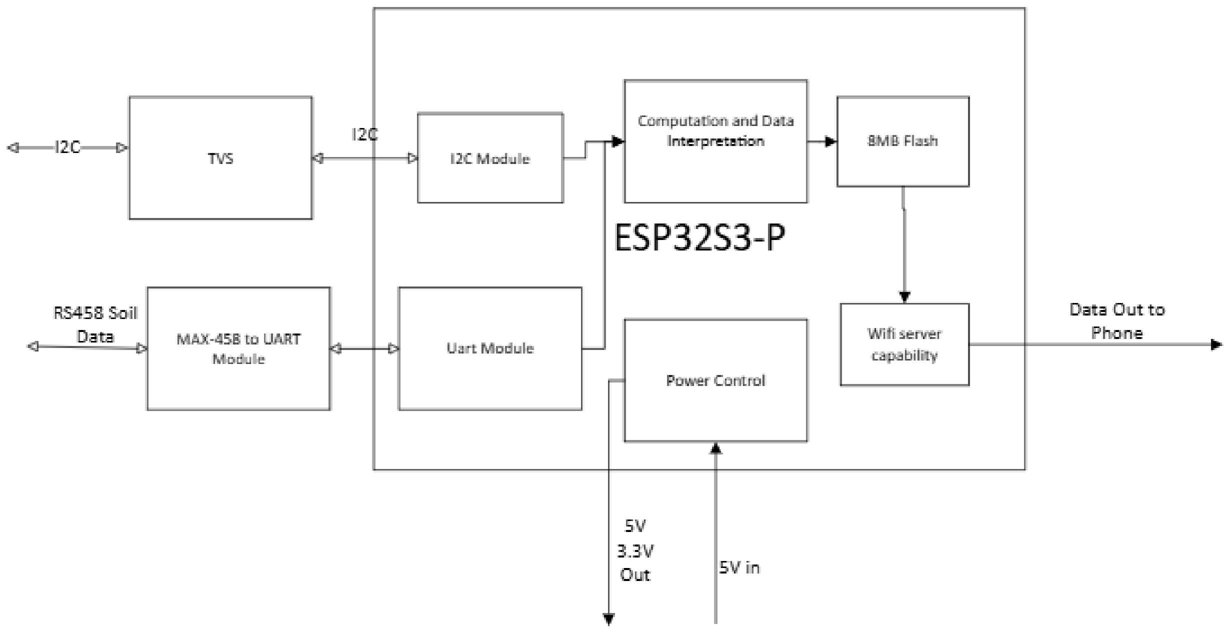
Outputs (energy, information, materials)	Soil Readings: Soil measurements sent to microcontroller via RS485
Functionality	The 7-in-1 Soil Sensor measures soil conductivity, potassium content, temperature, moisture, nitrogen content, pH, and phosphorus content, and sends this data to the microcontroller via RS485

Level 2 - Web Server Module:



Component	n/a
Inputs (energy, information, materials)	EVA Pod data STELLA data
Outputs (energy, information, materials)	Graphing and Map data User interface
Functionality	The web interface will collect the data from both pods and display them on a website. The data will record both location, timestamps, and display graphically. After which the data will be assigned to the location of the EVA pod or STELLA and the user can select the location on a map to view the data of that pod. Users can also then compare STELLA and EVA pod data.

Level 2 - Microcontroller Breakdown:



Components	ESP32S3-Pico-1, MAX485 RS485 to UART module, TVS Chip
Inputs (energy, information, materials)	5V from power conditioning, I2C data, RS485, UART Data
Outputs (energy, information, materials)	Wifi server data, 3.3V, 5V, I2C commands, UART commands
Functionality	This will take in data from the sensors, convert RS485 data into UART data, process the data and store it in the on-board flash memory. It will also manage power for sensors and run a LETIMER for efficient power use. Additionally this will provide data output to the user's phone or computer using Wifi.

Microcontroller Selection and Justification:

We will be using the ESP32-S3 because it has UART and I2C integration which will allow us to take data from all our sensors. The ESP32-S3 is readily available in the capstone lab and has already been used by our team for two of the sensors that we selected, the BME-688 temp/humidity sensor and the VEML-6030 light sensor. We will use another chip, the max-485, to translate RS-485 data from our soil sensor into UART to be used by the ESP. The ESP has Wifi communication capabilities for easy data upload in remote areas and enough flash memory to avoid storing data on a separate chip.

Technology Selections:

Technology Option	Maturity Risk	Complexity Risk
NPHKTHC-7 in 1 soil sensor	Low, commercially established technology	Medium, RS485 Protocol may be confusing
BME-688 temp humidity sensor	Low, commercially established technology	Low, already established working code
XENSIV PAS CO2 sensor	Low, commercially established technology	Medium, unknown to team but like other sensors we've used
VEML-6030 Light sensor	Low, commercially established technology	Low, already established working code
MAX-485 RS485 to UART	Low, commercially established technology	Medium, Unknown area and sending commands over UART may be confusing
ESP32-S3 Pico	Low, commercially established technology	Medium-Low, previously used in capstone class

Environmental Variance Analyzer (EVA) Pod

NASA Colorado Space Grant Consortium

Team Basically Wizards

Meet the Team

Julia DiTomas

RF, user interface

Anika Mathur

PCB, finance

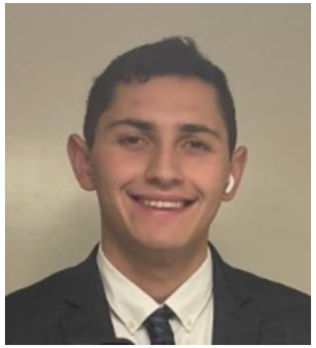
Shane McCammon

PCB, system architect

Sydney Medina

Primary contact, testing

Andrew Morris



Analog Design

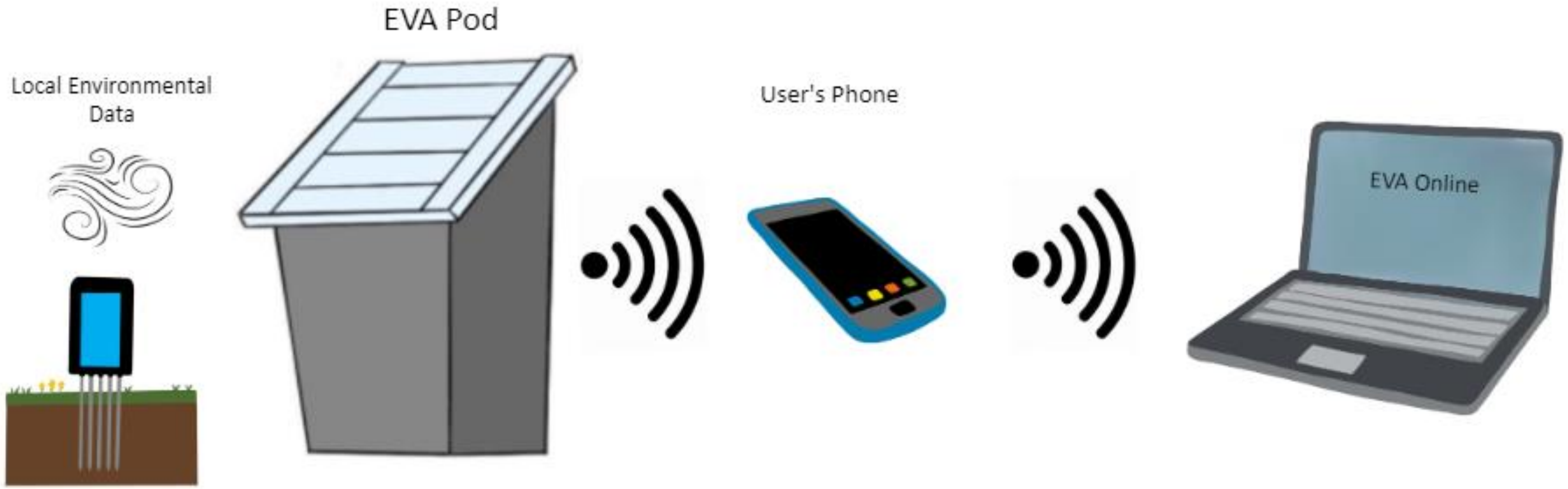
Eli Wall

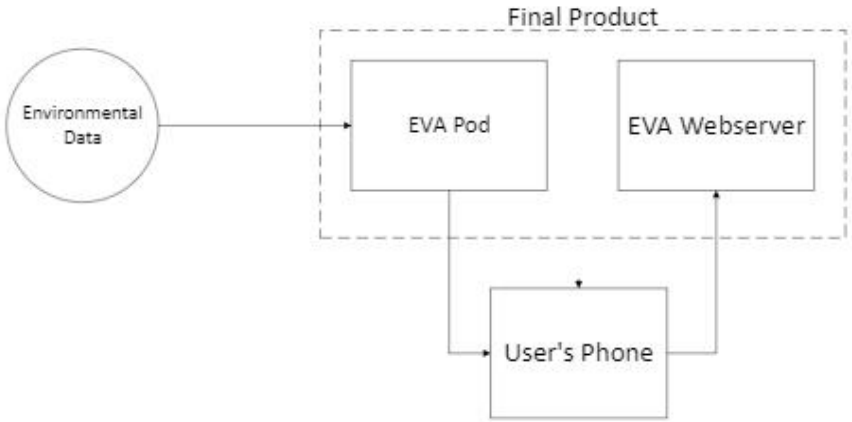
Team Lead, Embedded systems

Agenda

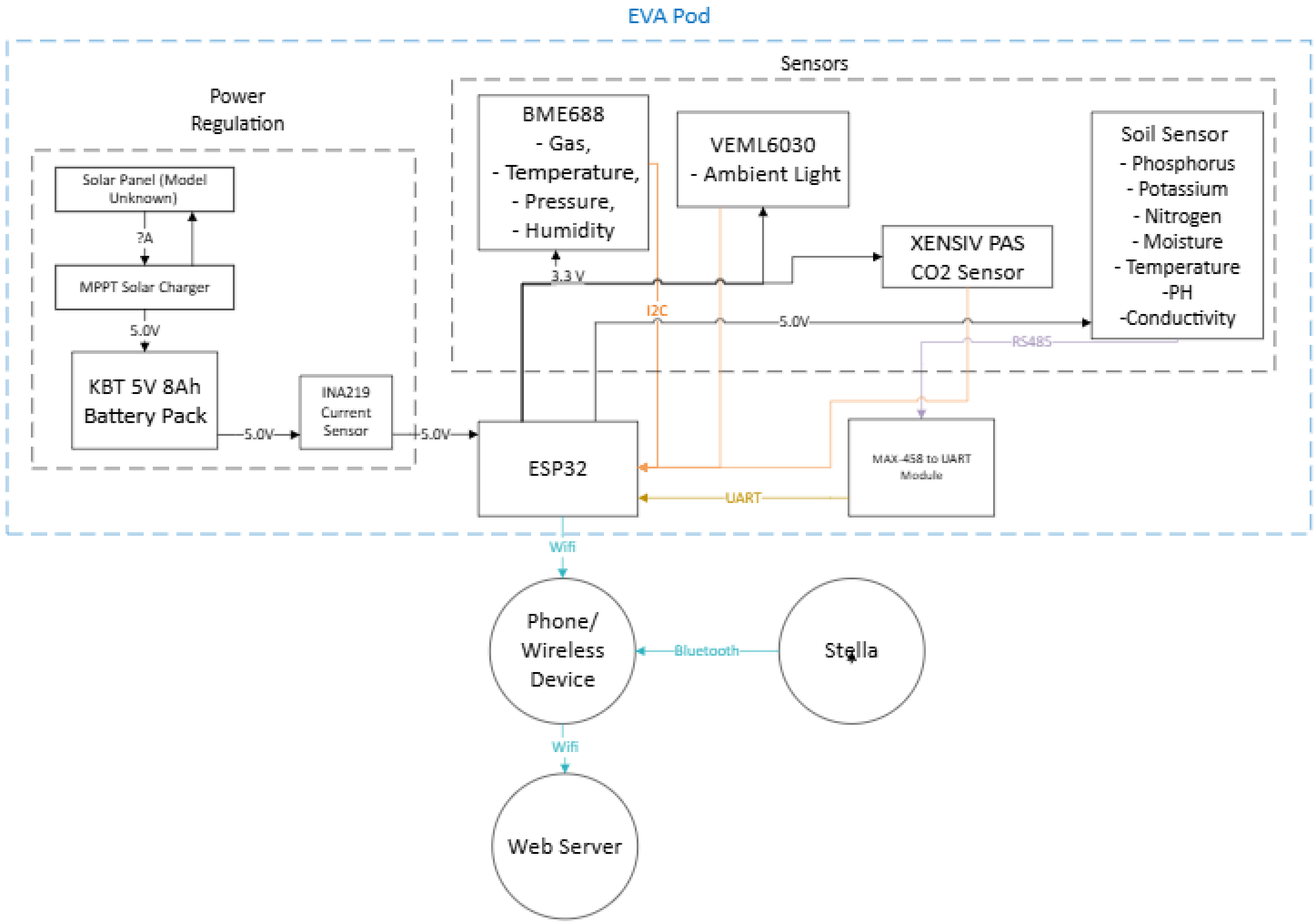
1. Project/Design Overview
2. Objective and System Overview
3. Phase Implementations
4. Sofware Development Plan
5. Power Budget
6. Risks and Mitigation Strategies
7. Project Budget

Overall Product Design

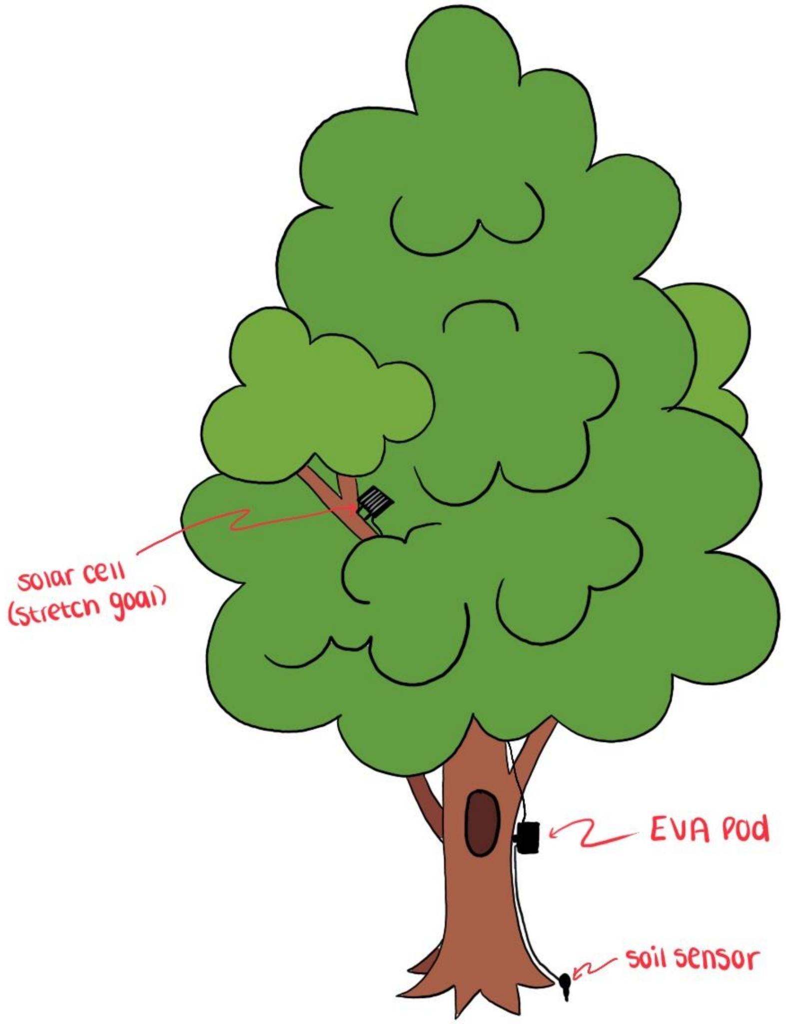


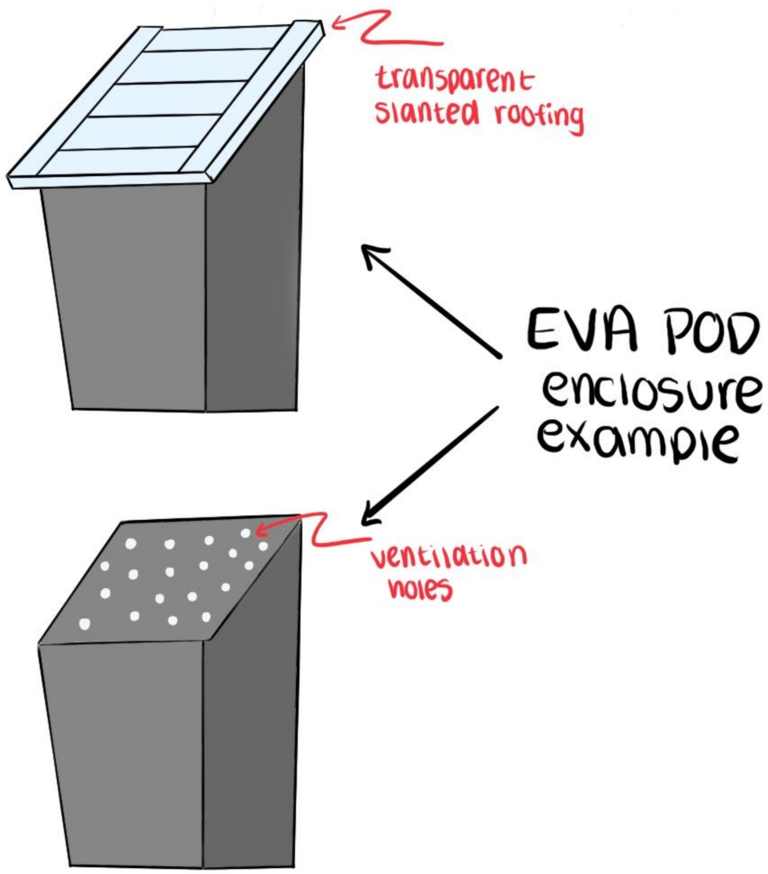


Functional Block Diagram



Project Design Overview





Product objectives and purpose of the system

Product Goals + Key Features

- Better understanding of local environment
- Collecting data to contextualize STELLA data
- Data locally stored and transferred via Wi-Fi for analysis
- Weatherproof enclosure
- Two-week battery life
- Minimal Cost

Sensor	Precision
CO_2	± 30 ppm
Temperature	± 0.5°C
Ambient Light	± 1 Lux
Humidity	± 3 %
Pressure	± 0.6 hPa
Soil	Varies for each of the 7 parameters

NASA Landsat Science

STELLA

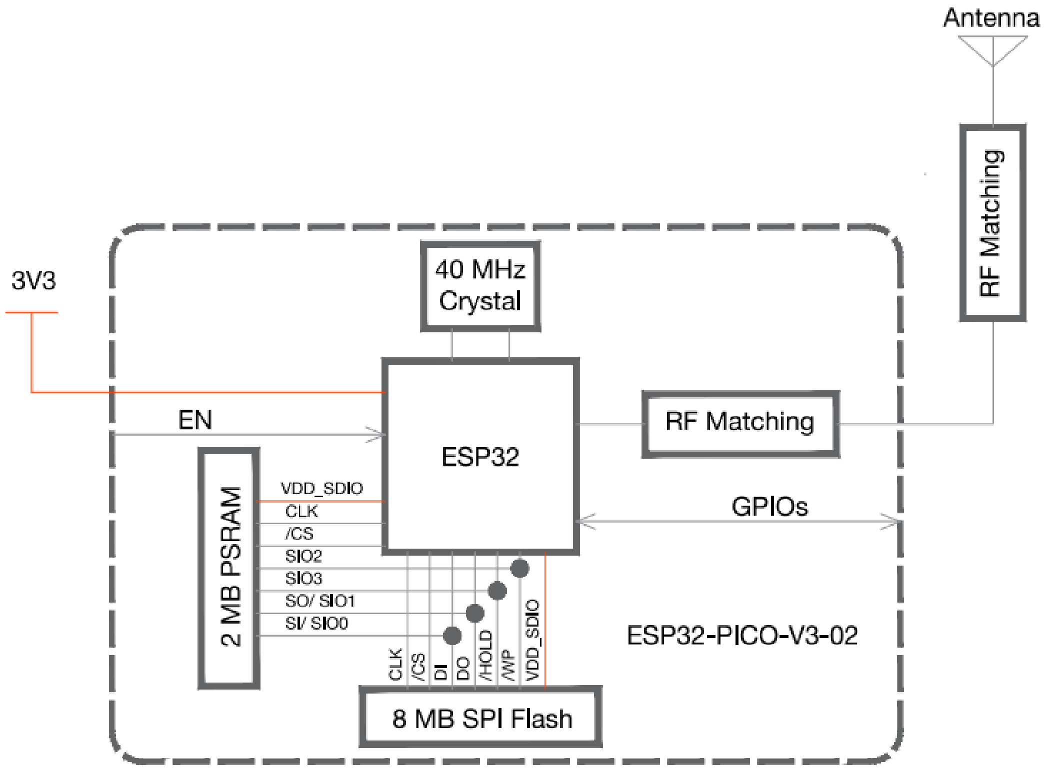
Technology Selection

- Sensors:
  - 7-in-1 Soil Sensor
    - NPKHCTH-S
  - BME688
    - Temperature
    - Pressure
    - Humidity
  - VEML6030
    - Ambient light
  - XENSIV PAS CO2
    - Air CO2 concentration
- Microcontroller:
  - RS485 Module
  - ESP32S3-P

Microcontroller Selection

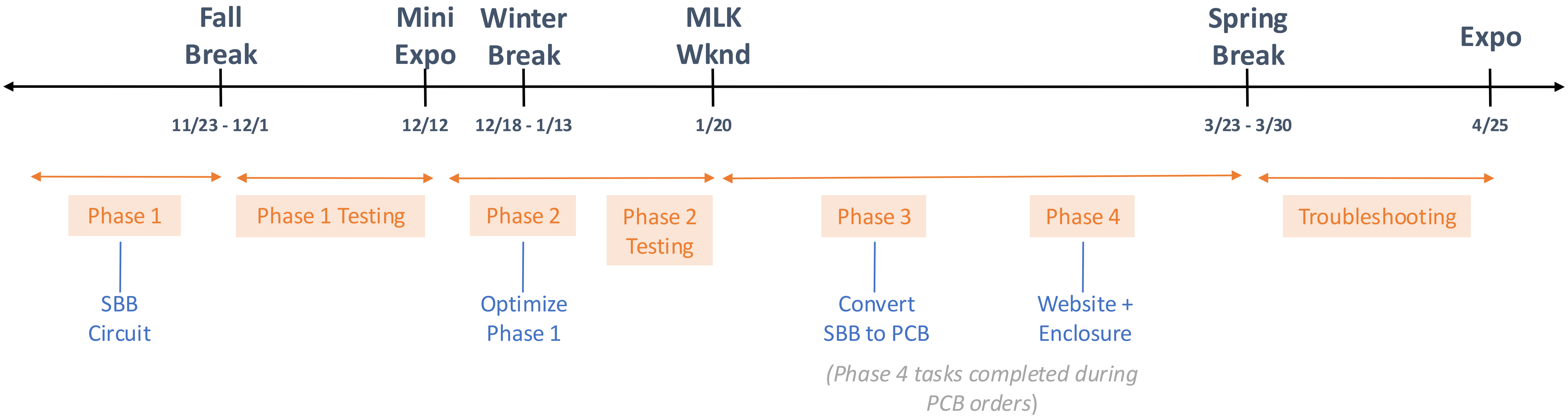
ESP32-S3 Pico

- Wi-Fi capabilities for easy upload
- Flash memory to store 2 weeks of data
- I2C and UART to communicate with sensors
- Low-risk, already used in IoT project



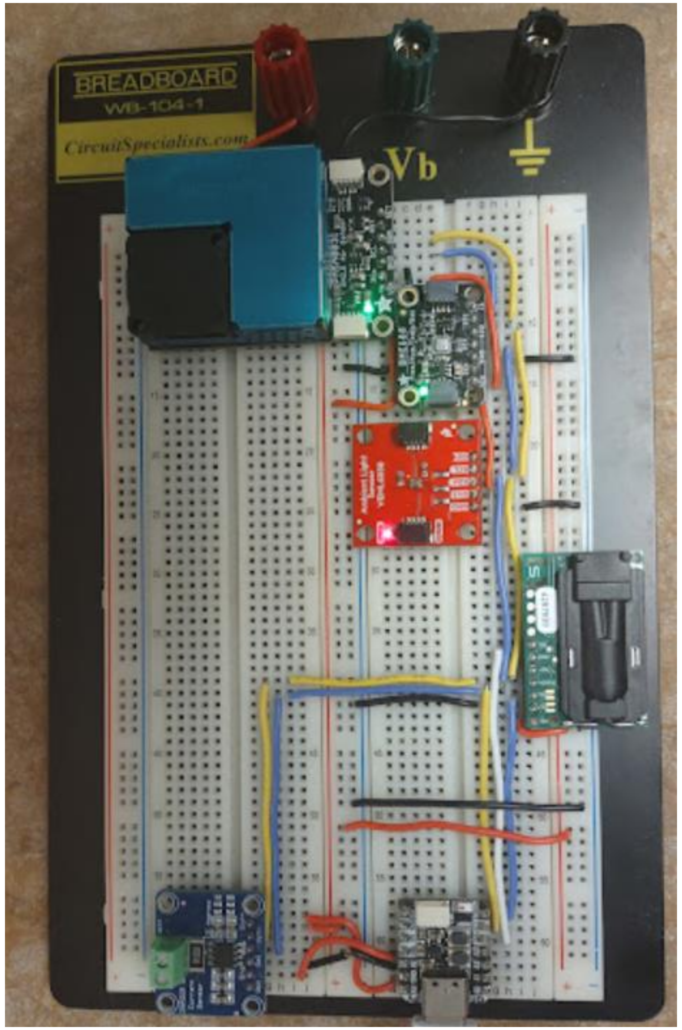
ESP32-PICO-V3-02 Block Diagram from Datasheet

Phase Implementation Timeline



Phase 1: SBB Circuit Design

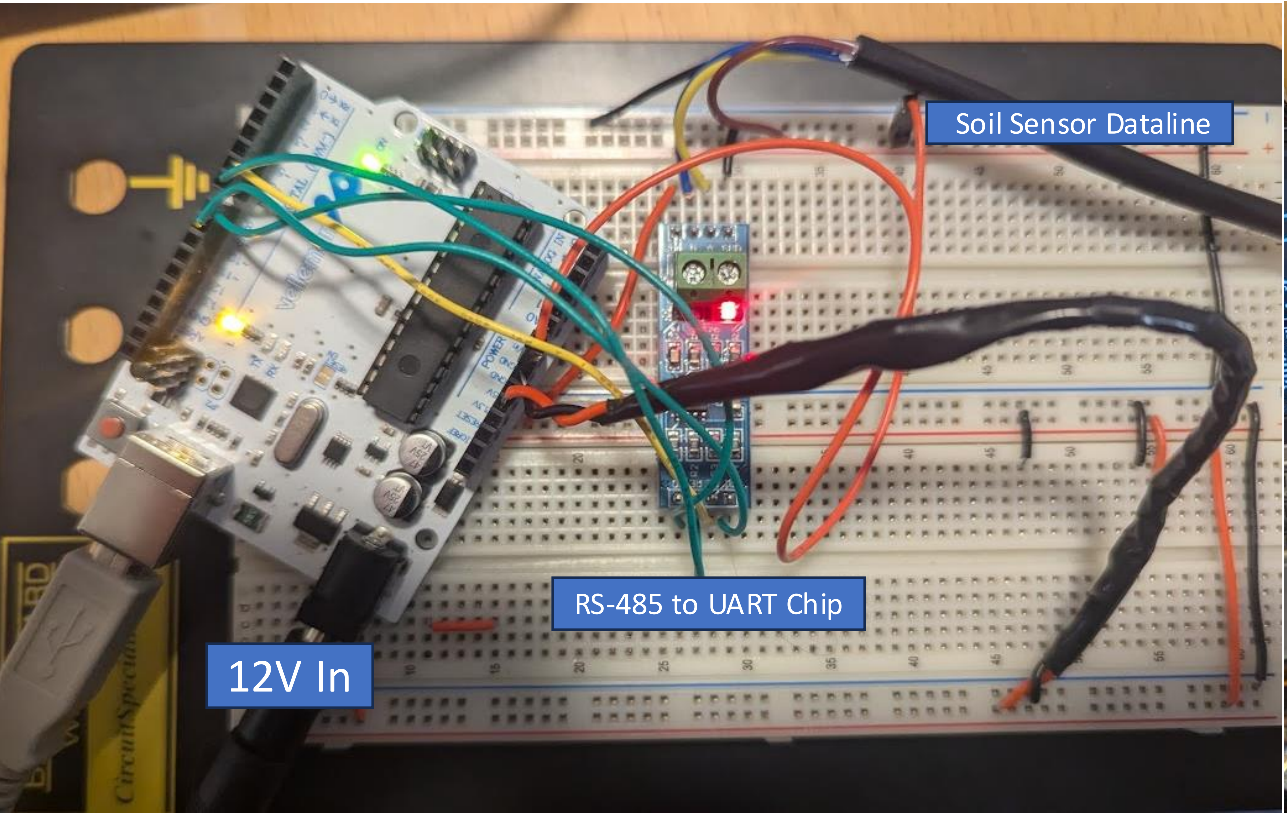
- Goal
  - Sensors consistently work cohesively and accurately together
  - Battery life ≥ 2 weeks
- All the sensors connected on a solderless breadboard
- Upload data to ThingSpeak
- Analyze and track goals

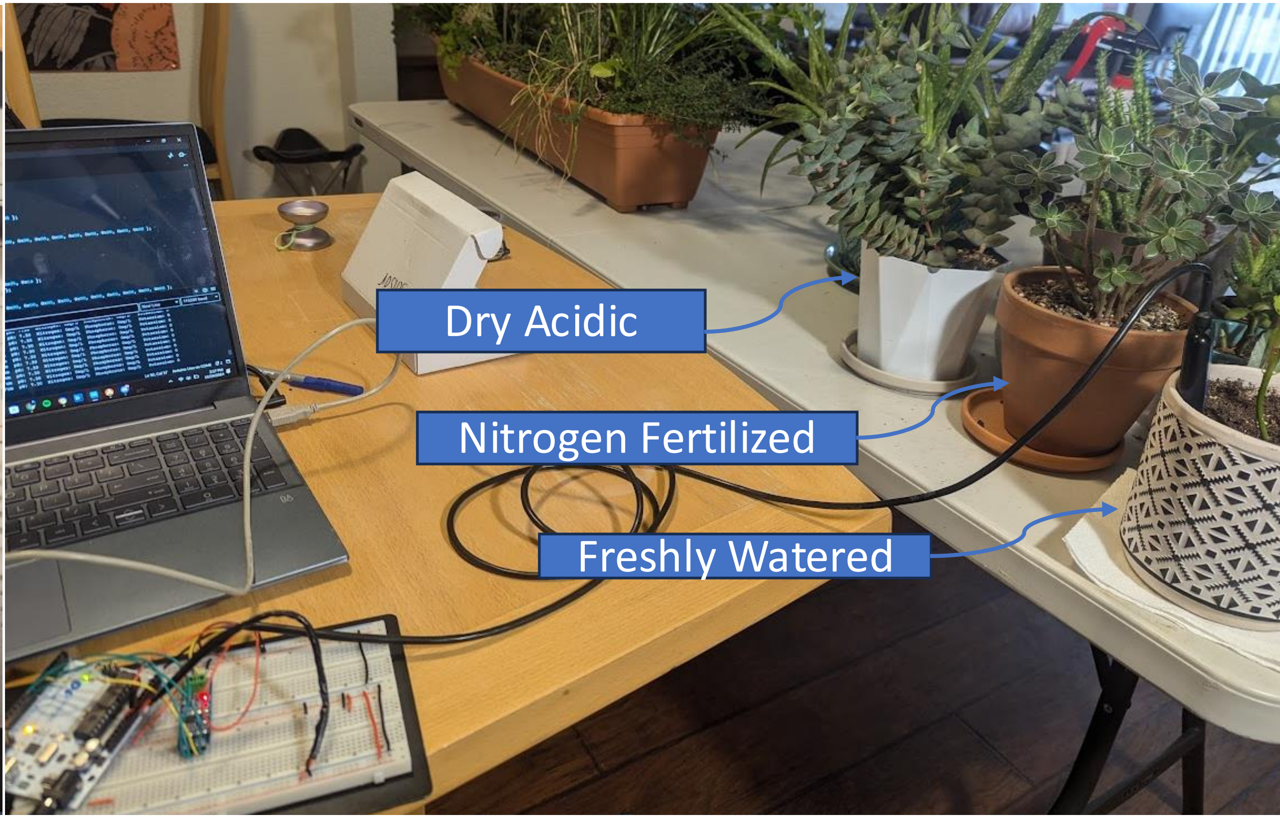


Phase 1 Test Plan

- Similar tests as the IOT workshop
- Battery and Power test:
  - Sit for 2 weeks unattended (Fall break)
  - Check on data through ThingSpeak
- Test the soil sensor by probing soil and view data on ThingSpeak
- Repeat soil sensor process with the VEML and BME sensors and test them overnight
- Initial testing inside lab

Soil Sensor Test Plan





Phase 2: Optimize Phase 1

- Field Testing
  - Round 2 battery test: We will let it sit unattended over winter break in the woods to
    - test battery life
    - Test data retention if it dies
  - Round 2 soil test: Probe known, modified soil and analyze the data on ThingSpeak
- Create Calibration Protocol
- Energy generation (stretch): On a sunny day, we will test the solar power generator for expected charge rate and output.

Phase 3: Convert SBB to PCB

- Design a custom PCB for each module
  - Power System
  - Microcontroller
  - Sensors (all)
- Test each PCB separately, then combine and repeat Phase 2 tests

Power Control PCB
power jack & current sensor
(STRETCH: solar input, buck boost converter)

Microcontroller PCB
(ESP32 + RS485 module)

Sensor PCB
Soil sensor, BME688, VEML6030, XENSIV PAS CO_2 sensor

Phase 4: Website Build & Enclosure Design

Website

- Build custom website that will display the EVA Pod and STELLA data
- The website will match timestamps to each pod and location so users can click on the data on a Google Map API sort of interface

Enclosure

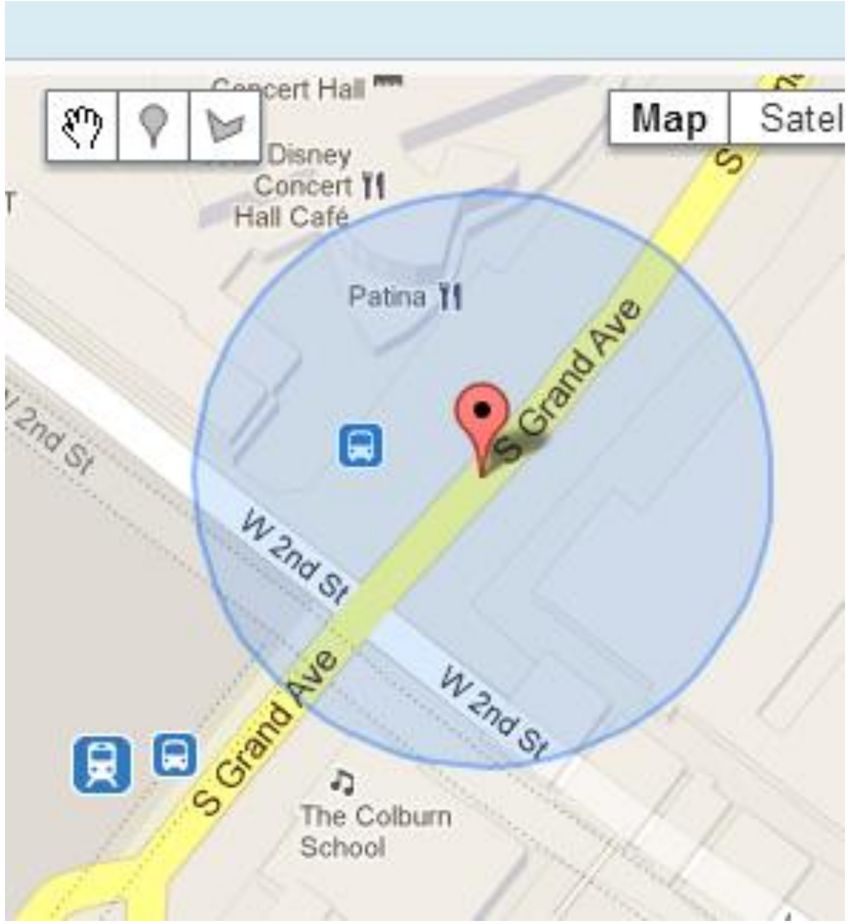
- Research materials that are weather resilient to hold the circuit elements
- Start with 3D printed enclosure designs and then iterate to more sturdy materials

Testing

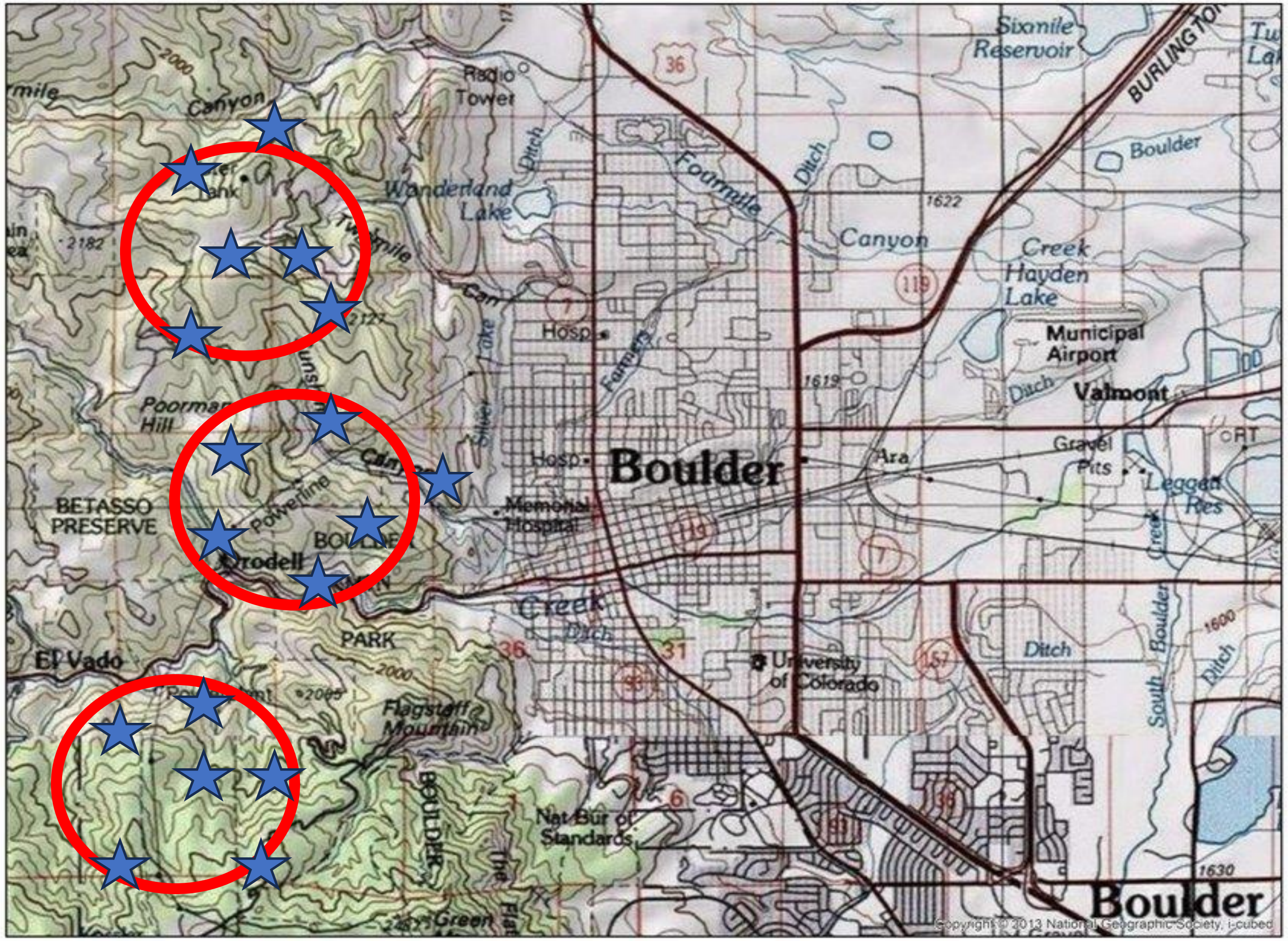
- Take final EVA pod out to a forest environment
- See if collected data uploads to website correctly and accurately
- Does it contextualize STELLA data?
- Is the enclosure best fit for the environmental factors?

Software Development Plan

- Using ESP32-S3 Pico / Arduino IDE
- Sensor configuration, I2C, MODBUS, UART, Wi-Fi protocols
- Web Server to download data from EVA Pod
- User Interface with maps API to display data to community
- Potential risks
  - Energy management
  - EC data conversion
  - NPK data.



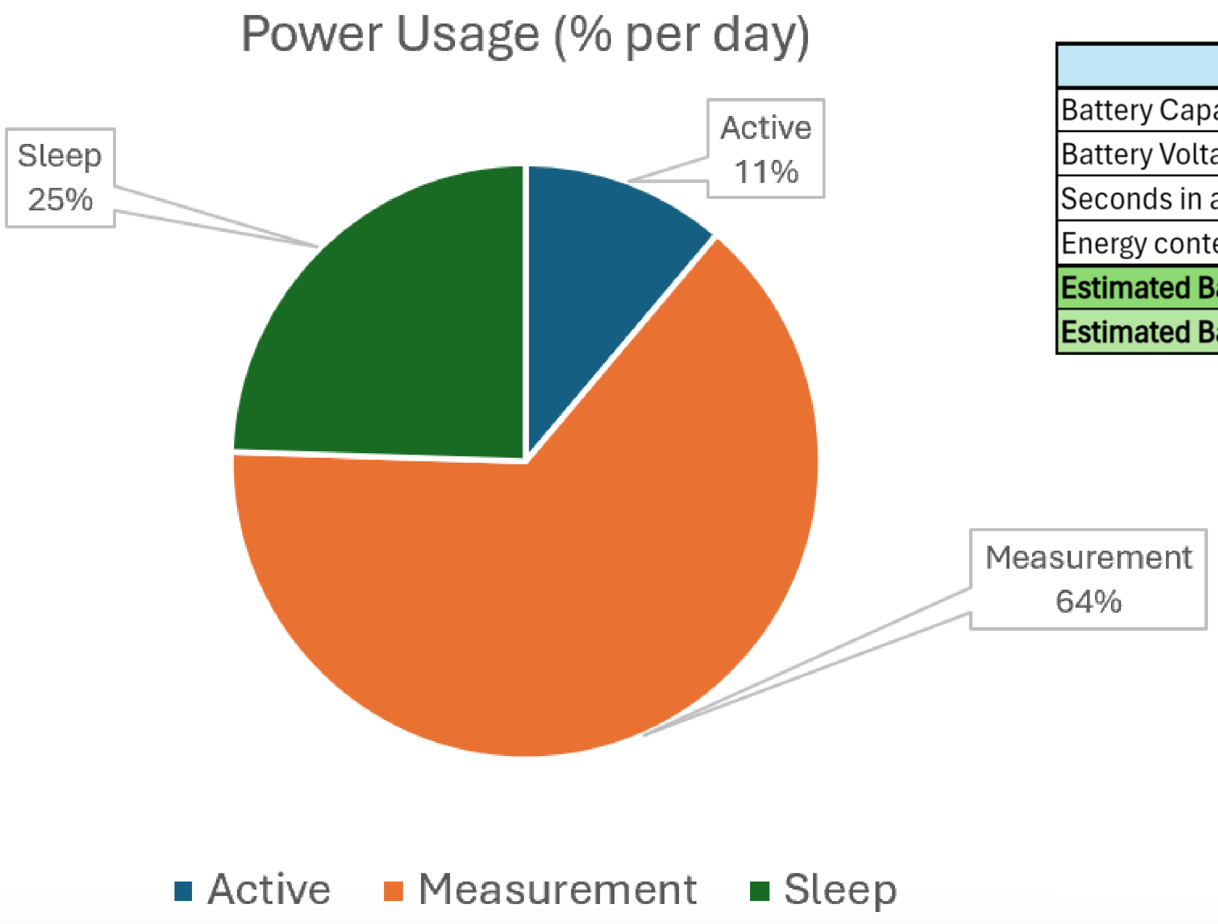
Map API Example



EVA Pod radius

Stella Readings

Power Budget



Battery Life Estimate	
Battery Capacity (Ah)	4
Battery Voltage (V)	5
Seconds in an Hour	3600
Energy content in the battery (Joules)	72000
Estimated Battery Life (Hours)	**473.9458777**
Estimated Battery Life (Days)	**19.7477449**

- Data represents model with little optimization
- Collecting data 6 times in 24hrs

Project Risks, Test Plans and Mitigation Strategies

Risk	Phase 1 Testing	Plan B
Insufficient power	Check that design operates for 2 weeks on a single battery charge	Bigger or new battery (raises cost)
Communication with Soil Sensor	Obtain readings of all 7 parameters measured by sensor using MAX485	Use a different soil sensor, such as Adafruit's (descopes project, less parameters measured)
Enclosure not waterproof enough for extreme weather	Test enclosure for weatherproofing by spraying water from a nozzle for 5 and 10 minutes, then test functionality.	Explore alternative waterproofing techniques such as chemical coatings.
Unit cost < \$300	Calculate total cost of phase 1 prototype and estimate final unit cost	Descope project
Utilizing JavaScript for Google Maps API	Create 1 location pin and upload EVA Pod data into at least 1 graph	Remove map interface and move to drop down menus of data
Inaccurate sensors	Compare data taken by EVA pod with data taken by known, accurate sensors	Explore alternative sensors or recommend EVA calibration

Project Budget

Material	Total Price
Microcontroller System (ESP-32, RS485)	$10.00
Sensors	$80.00
Power System	$27.00
Custom PCB Orders (JLC)	$200.00
Enclosure Materials	$110.00
Mounting Materials	$20.00
Solar Materials	$60.00
Misc Hardware	$50.00
Contingency	$50.00
Total	**$607.00**

Conclusion

- The EVA Pod will utilize an assortment of thoroughly tested sensors over an extended period to aid in characterizing an environment.
- When paired with the NASA STELLA, data will be analyzed and cross referenced for comprehensive characterization of the environment.

Thank You!

Questions?

Supplemental Power Calculations

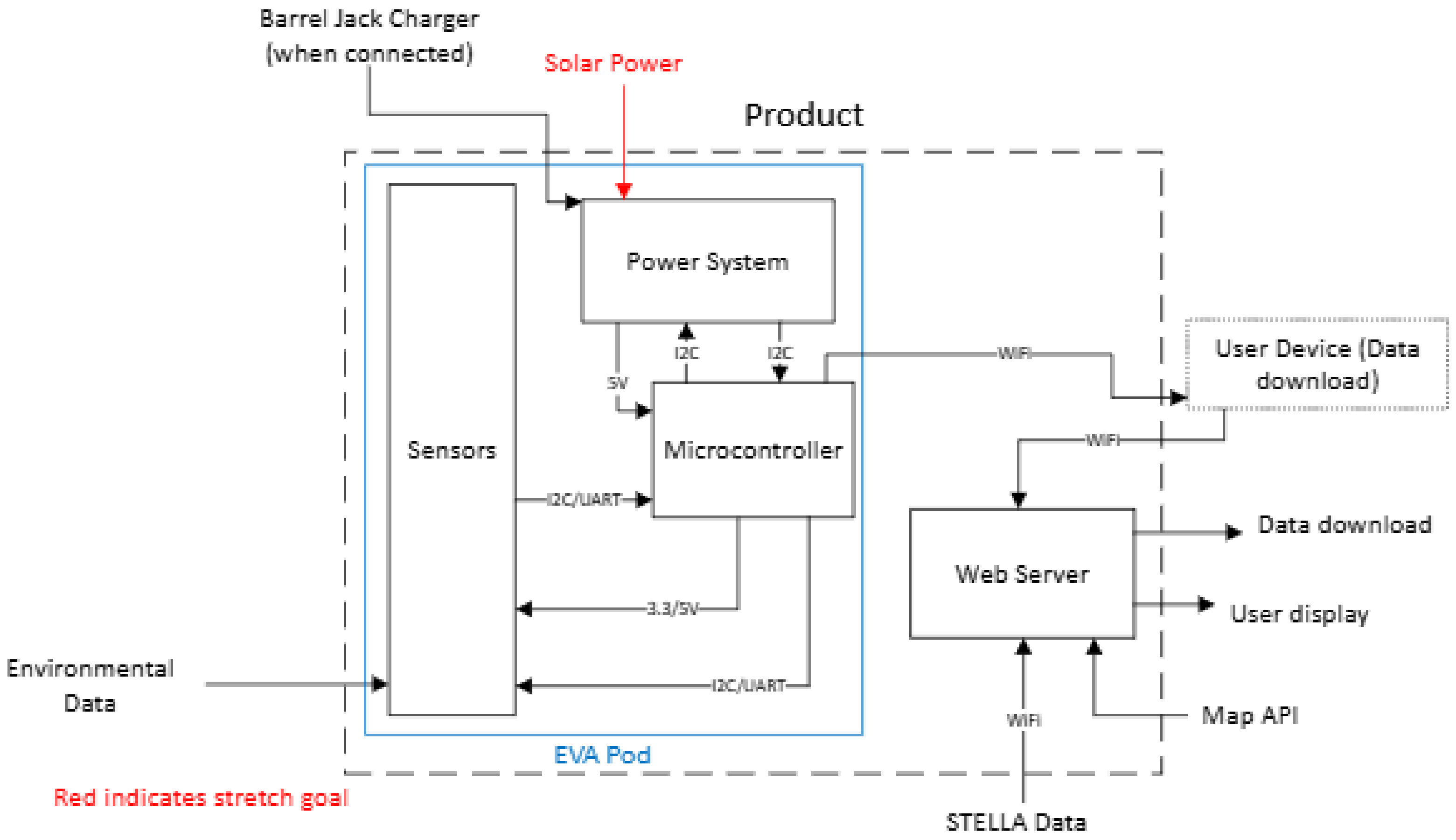
Device	Current (uA)	Voltage (V)	Power (uW)		State 1 [Active]	State 2 [Measure]	State 3 [Transmit]	State 4 [Sleep]
Power Supply Quiscient			0					
MCU Active [RF]	130000	3.3	429000				X	
MCU Active [NO RF]	108000	3.3	356400		X	X		
MCU Deep Sleep	8	3.3	26.4					X
MCU OFF	1	3.3	3.3					
7-1 Soil Sensor (Active)	20000	5	100000			X		
7-1 Soil Sensor (Sleep)	6	5	30		X		X	X
7-1 Soil Sensor (Q-Current)								
Ambient Light VEML6030 (Active, 4100ms refresh)	2	3.3	6.6			X		
Ambient Light VEML6020 (Q-Current)	0.5	3.3	1.65		X		X	X
Gas/Pressure/Temp/Humidity BME688 (active)	12000	3.3	39600			X		
Gas/Pressure/Temp/Humidity BME688 (Q-Current)	0.15	3.3	0.495		X		X	X
RS485-UART MAX485 (active)	900	5	4500			X		
RS485-UART MAX485 (Q-Current)	10	5	50		X		X	X
				Peak current (uA)	108016.65	140902	130016.65	24.65
				State Power (uW)	356482.145	500506.6	429082.145	108.545
Efficiency 65%								
Efficiency 85%				X	X	X	X	X
				Time % (per day)	0.0006944444	0.002802292	0.00000000000	0.996503264
				Weighted Power Consumption (per day)	291.2435825	1650.077029	0	127.2534668
				Total Power Consumption (uW/day)	**2068.574078**			
				State Power (Watts)	0.356482145	0.5005066	0.429082145	0.000108545
				Usage (secs)	60	242.118	0	86097.882
				Weighted Energy Usage (Joules)	21.3889287	121.181657	0	9.345494602
				Total Energy Usage per day (Joules)	**151.9160803**			

States	State Description
State 1	Active[No RF]
State 2	Measure
State 3	Transmit
State 4	Sleep
State 5	

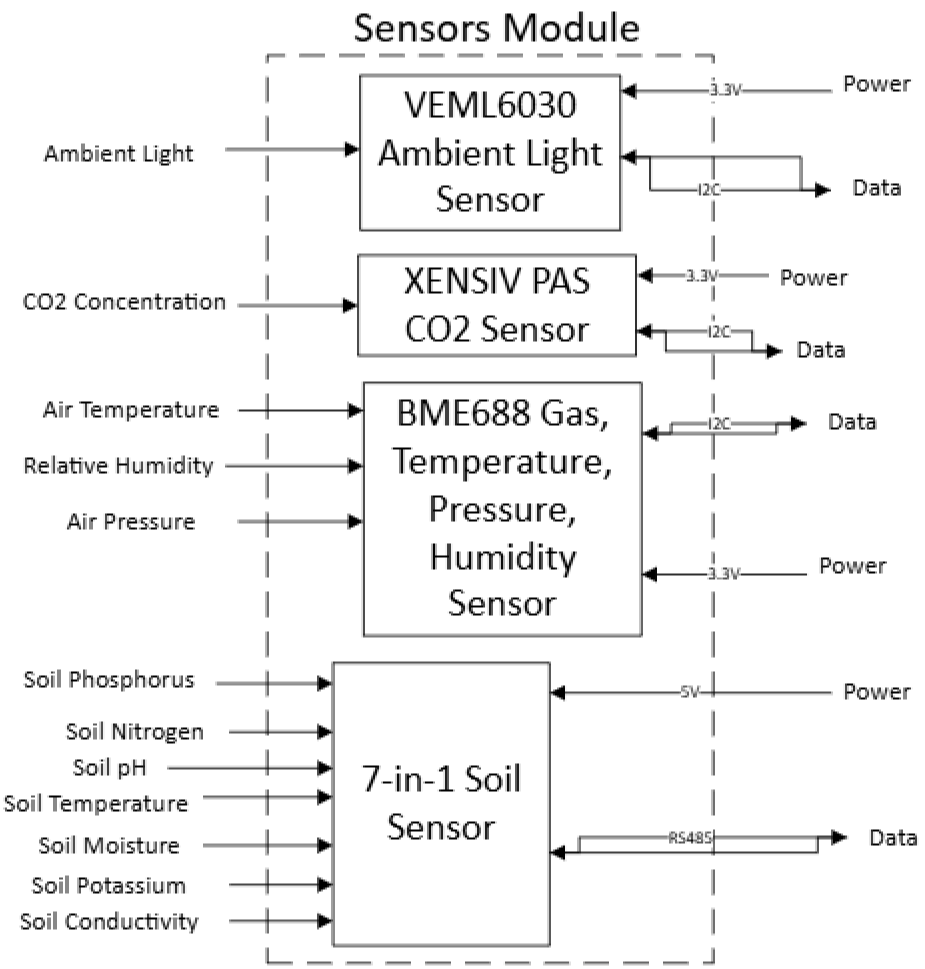
Sensor Action	Measurement Time(ms)	States invoked	Total times used per 24 hours	Total Usage (ms)
Soil Measure	20000		6	120000
BME688 Measure	253		6	1518
VEML6030 Measure	100		6	600
MAX486 Active	20000		6	120000
MCU Active [NO RF]	10000		6	60000
MCU Active [RF]	3000		0	0
MCU Measure	40353		6	242118
Sleep	-		-	86097882
			Milliseconds in a day	**86400000**

Battery Life Estimate	
Battery Capacity (Ah)	4
Battery Voltage (V)	5
Seconds in an Hour	3600
Energy content in the battery (Joules)	72000
Estimated Battery Life (Hours)	**473.9458777**
Estimated Battery Life (Days)	**19.7477449**

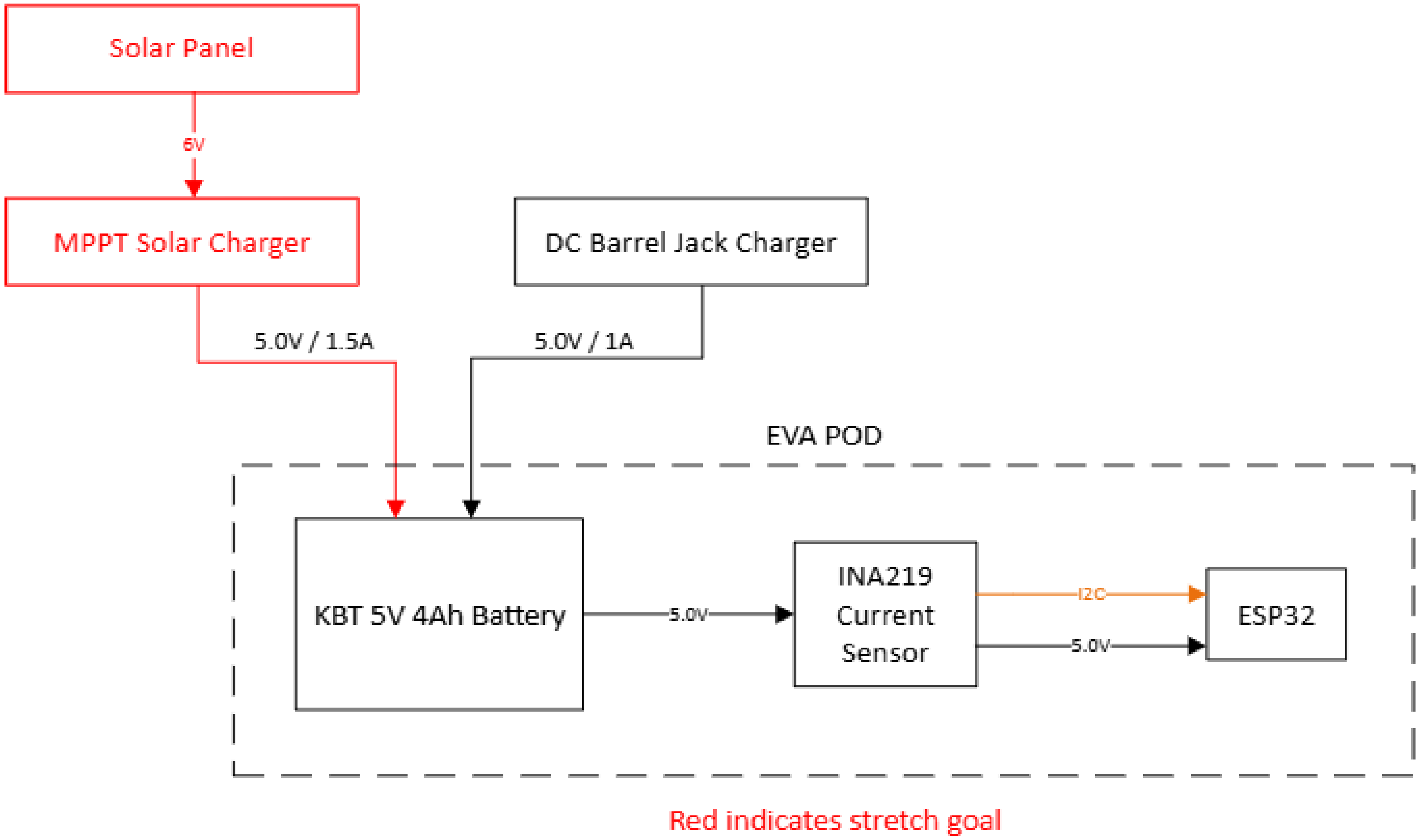
Level 1 Decomposition



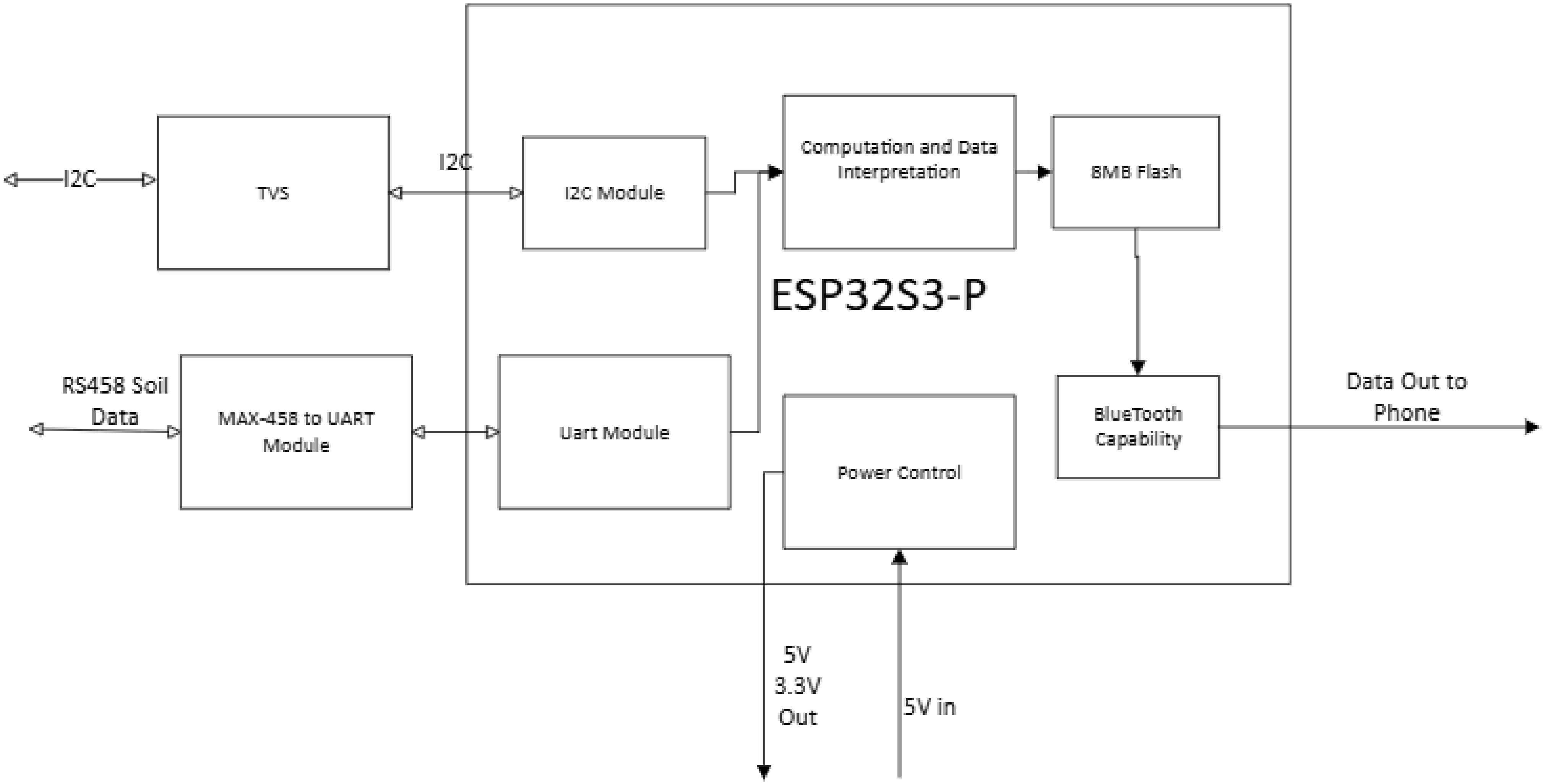
Level 2 Decomposition - Sensors



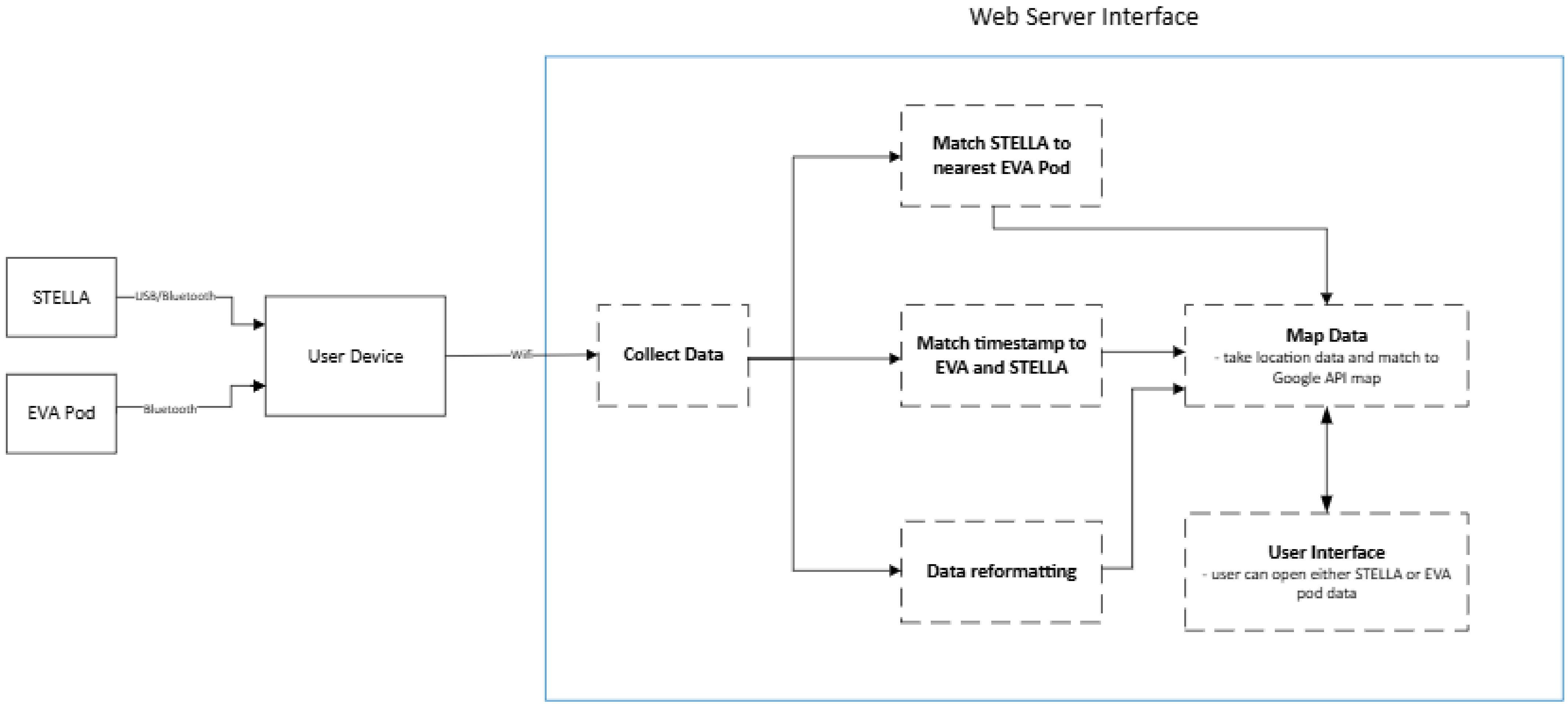
Level 2 Decomposition – Power System



Level 2 Decomposition – Microcontroller



Level 2 Decomposition – Web Server



Technology Selections

- Sensors: 7-in-1 Soil Sensor, BME688, VEML6030
- Microcontroller: RS485 Module, ESP32S3-P

Technology Option	Maturity Risk	Complexity Risk
NPHKTHC-7 in 1 soil sensor	Low, commercially established technology	Medium, RS485 Protocol may be confusing
BME-688 temp humidity sensor	Low, commercially established technology	Low, already established working code
VEML-6030 Light sensor	Low, commercially established technology	Low, already established working code
XENSIV PAS CO2 sensor	Low, commercially established technology	Medium, unknown to team but similar to sensors we've used
MAX-485 RS485 to UART	Low, commercially established technology	Medium, Unknown area and sending commands over UART may be confusing
ESP32-S3 Pico	Low, commercially established technology	Medium Low, previously used in capstone class

Itemized Project Budget

Material	Unit Price	Quantity	Total Price
Technology			
Microcontroller (ESP-32)	$0.00	1	$0
BME688 (Gas, Temperature, Pressure, Humidity Sensor)	$0.00	1	$0
Ambient Light Sensor (VEML 6030)	$0.00	1	$0
RS485 7 in 1 Soil Sensor (NPKPHCTH-S)	$68.00	1	$81.39
RS-485 Module (x5) (MAX485)	$8.99	1	$8.99
Manufacturing			
JLC PCB	$0.00	--	$0.00
Extra PCB Parts + Assembly Costs	$200.00	--	$200
Battery Pack	$15.99	1	$15.99
Current Sensor	$9.95	1	$9.95
Enclosure			
3D Printing Filament	$0.00	--	$0
Waterproof 3D Filament	$30.00	2	$60
Acrylic	$25.00	2	$50.00
Hardware (nuts, bolts, screws, o-ring)	$50.00	--	$50
Velcro Strap (mounting)	$20.00	1	$20
Solar Materials			
Lipo Charger (x2)	$6.49	1	$6.49
Buck Boost Converter (x3)	$9.99	1	$9.99
Solar Panel	$18.99	1	$18.99
Battery (3.7V)	$24.99	1	$24.99
Contingency	$50.00	--	$50.00
		Total	**$607**

Test Plan Demo Sheet (Power Draw)

TEAM NAME: Basically Wizards **Test Date & Time: Fall Break and 12/3/2024 10:30 am**

Test #1: Power Draw test **Test Type:** P/F (ultimately)

1) List ALL of your major risks in your project. Circle the one you will be testing in this test:

Risk
Insufficient power
Communication with Soil Sensor
Enclosure not waterproof enough for extreme weather
Unit cost < $300
Utilizing JavaScript for Google Maps API

Information: Based on the info gathered from this test, we will know the power draw of each sensor/ fan/ component, and we will be able to calculate if it will last for the 2-week minimum.

Purpose: This project is intended to be a deployable pod that a team/individual will not have to

maintain/ visit frequently to keep gathering information. A 2-week battery life will satisfy the low maintenance requirement.

Importance: One of the only concrete requirements from the sponsor was a 2-week battery life.

2) What is your test plan? What exactly will be tested, and how will you perform the test? :

To test out how long the battery life lasts, we will let the EVA pod sit on its own during Fall and Winter break. During this time, the EVA pod will collect data and we will measure the power and current draw. This way, we can reconduct our power measurements with actual values of how our pod behaves. Best case, we will allow our pod to sit for 2 weeks, however if that is not possible, we will simply scale our calculations based on the amount of time we let it measure and collect data.

The results will determine whether we are well within the requirement, well outside of the requirement, or within reach of it. The risk of a pod dying in the field is currently very high as we haven't performed any characterization of our current (on-hand) sensors. After we perform the test, our risk will be lowered as we will have more certainty of the anticipated performance. Based on the results, we will assess if we need to move to solar power generation, invest in a larger battery, or change our selection of sensors to be more efficient with the power we have.

3) Test Procedure and anticipated results (Brief, concise, but complete, description):

For the initial Fall break test, we will run our sensor array through a fully charged battery. The current draw will be monitored through a INA219 in-line current sensor and the data will be hosted on Thingspeak for analysis. Our current calculations show that we estimate an energy usage of 152 Joules per day and we will use this to compare with our empirical data. Meeting or exceeding this energy will be a metric of success. The Winter break test will be similar but for a longer duration (all of winter break) and will also include more extreme environmental conditions such as being exposed to winter weather.

4) Test results. What did you measure, observer or otherwise extract from this test?

What we expected: Current draw in sleep mode: 24uA, measurement mode: 140mA, transmit: 130mA
What we measured: Current draw in sleep mode: 44mA, measurement mode: 55mA, transmit: 160mA

EVA Pod state	Expected current	Measured current
Sleep	24 uA	44 mA
Measure	140 mA	55 mA
Host wifi server	130 mA	160 mA

Interpretation: Sleep mode is consuming much more power than calculated while transmit mode is high but near expected and measurement mode is much lower than expected.
Do the results make sense: Yes, assuming that there could be an error with software or higher than expected q-currents.
[Type here]

Consistency tests: Weekend testing and two week test to see that the battery performs as expected (winter break)

5) Test outcome and what was learned (toward finalizing design):

Based off of our current measurements, our device consumes too much power to last two weeks. It did not succeed lasting over fall break; instead it lasted 3 days, which is due to the high current draw while sleeping. Currently it is consuming about 3823 Joules per day rather than our calculated value of 152 Joules per day. There needs to be further investigation into quiescent currents and MCU low power programming.

6) Instructional Team Notes:

Test Plan Demo Sheet (Sensor Accuracy)

TEAM NAME: Basically Wizards **Test Date & Time: 12/3/2024 10:30 am**

Test #2: Sensor Accuracy **Test Type:** Characterization

1) Major Risk:

Risk
Insufficient power
Communication with Soil Sensor
Enclosure not waterproof enough for extreme weather
Unit cost < $300
Utilizing JavaScript for Google Maps API
Inaccurate sensors

Purpose: The purpose of this test is to characterize the accuracy of all data measured by the EVA pod.

Impact: If the accuracy of any data is unacceptable by our sponsor's standards, we may need to research and purchase new sensors. For all data measured by the EVA pod, we will provide accuracy specifications to the users.

Importance: This is an important risk for Phase 1 testing because the purpose of the EVA pod is to measure environmental data and have it comparable across different sites. Citizen scientists using the product should also be informed of the uncertainty.

2) Test Plan and Scope:

This test plan will be testing the accuracy of each of our sensors. We have three varieties of sensors; Soil Sensors, Air quality sensors, and miscellaneous sensors.

- Soil sensors:

Test using a commercial soil sensor that we have access to in the lab and then compare our soil sensors to it. In this, we will be measuring a variety of values, from nitrogen levels to conductivity to soil moisture. We will be measuring a specific soil sample, and then do the same with our soil sample.

- Air Quality sensors

Test using the commercial air quality sensors available in the lab and then compare our CO2 and other air quality sensors to it. We will be measuring the Hydrogen and C02 content in the air and comparing them to the measurements we get from the commercial air quality sensor.

- Miscellaneous sensors

Test using a combination of sensors which have been verified in lab and compare our light and current sensor to the trusted data. We will be measuring lumens and microamps with tools available in the lab and comparing them with the values measured by the sensors.

3) Test Procedure and anticipated result:

1) First, remove external sources of error (For light sensor, move to a dark room, or create a small dark space)
2) Use commercial/trusted sensor to collect data values (Finding lumens output by a light source
3) Collect values from our sensors. (Finding lumens output by the same light source, from the same position
4) Compare the difference. (Do data analysis, comparing a variety of data points to calculate an average difference between measurements, and a trendline to help improve overall data collection.)
5) Create adjustment algorithm. (Use previously calculated metrics to alter our sensor to measure the same values as their sensor.
6) Retest to verify results consistency (Retest, completing steps 2, 3, and 4)
7) Fix adjustment algorithm if necessary and retest values. (If step 6 results in a difference between the two sensors, repeat the data analysis, and correct for the difference, going back to step 6.

4) Test results:

This is the most important part. What did you measure in your test and what does it mean? How are you interpreting your measurements? Do the results make sense? Are there any consistency tests you can think of doing to help support your interpretation? Do your conclusions follow from your measurements or observations?

Accuracy of QingPing Air monitor: ±15%
Accuracy of Soil Test Kit:
-pH: ±1
-Nitrogen: ±50%
-Phosphorus: ±50%
-Potassium: ±50%

Parameter	Comparison Measurement	Expected Range	Observed	Agreement?
Temperature (degrees Celsius)	24.9	21.2 - 28.6	26.6	Yes
Relative humidity (%)	20.2	17.2 - 23.2	18.2	Yes
pH	7	6 - 8	5.8	No
Nitrogen (mg/L)	5	2.5 - 7.5	1	No
Phosphorus (mg/L)	80	40 - 120	48	No
Potassium (mg/L)	240	120 - 360	41	No

5) Test outcome and what was learned

Prior to presenting your test demo to the instructor team, you will have performed the test internally multiple times. Describe the results of the test and the lessons learned. What is the so what? Based on your measurements and observations, how will you change your product design path?

We have not tested the accuracy of every data point at this time, but from what we have seen, the air temperature and air humidity are in agreement with the commercial sensor and have at least the accuracy of that (15%). The soil nutrients are not in agreement with the chemical test kit, so we will look into calibrating it in the code or finding other ways to measure soil NPK.

6) Instructional Team Notes:

N/A at this time