Environmental Variance Analyzer (EVA) Pod

NASA Colorado Space Grant Consortium

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Sydney Medina, Andrew Morris, Eli Wall

Project Overview

Project Name: An Environmental Monitoring Pod for Community Engagement

Product Name: Environmental Variance Analyzer (EVA) Pod

Sponsor: NASA Colorado Space Grant Consortium

Team Name: Basically Wizards

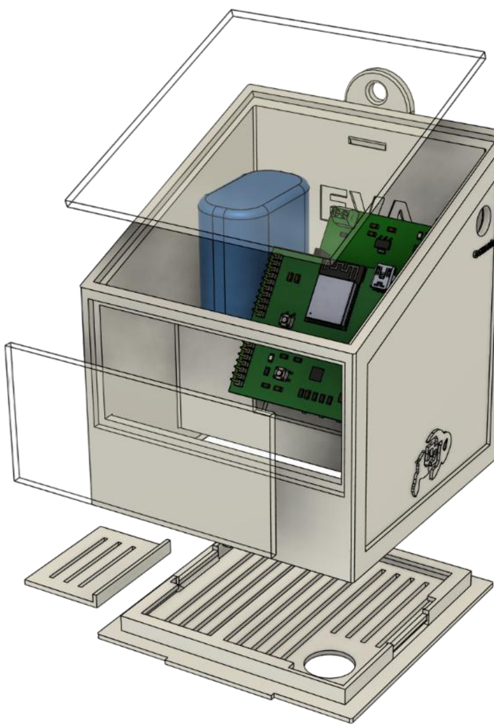
Team Members:

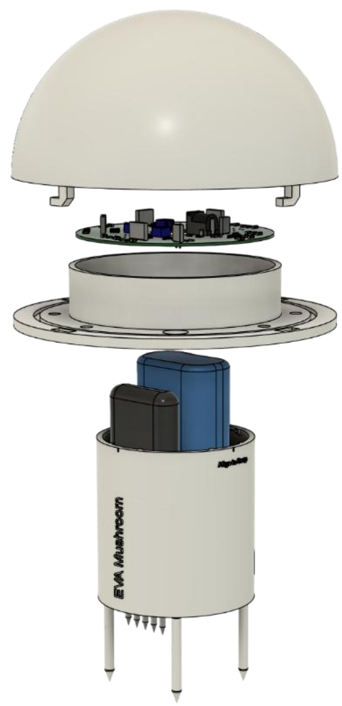
Julia DiTomas Role: Website Design Lead, User Interface	**Anika Mathur** Role: PCB Lead, Enclosure Designer, Finance Lead	**Shane McCammon** Role: Power Lead, Enclosure Designer, PCB Designer
Sydney Medina Role: Client Contact, User Interface	**Andrew Morris** Role: Analog Design Lead, Backend Website Design	**Eli Wall** Role: Team Lead, Embedded System Lead

Abstract

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. The EVA Pod has two modules associated with it, the EVA itself as well as the MOSS (Mushroom Off-gassing Soil Sensor). The EVA measures temperature, humidity, CO_2, and light, while the mushroom measures soil properties and off-gassing. The EVA Pod also has a website interface where data can be uploaded and displayed to compare with the NASA STELLA Module data. The website utilizes Google Maps API, and users can see community EVA pod locations on the map to see local environmental data.





Project Requirements

Marketing Requirements

- The EVA Pod is low cost, which maximizes accessibility and allows students and citizen scientists to benefit from it.
- 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.
- The EVA Pod and MOSS are compact and blend into the environment to easily carry to sites and mount. The EVA Pod is shaped like a birdhouse and the MOSS is shaped like a mushroom for aesthetic purposes.

Engineering Requirements

- 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 timestamped, geotagged, and in like units, to allow users to use both products in tandem to gain a full contextualization of the environment.
- Weatherproof enclosure, giving the user confidence that it will survive the elements and keeping safety of the environment as the top priority.

Technology Selection

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

Sensors

- 3-in-1 Soil Sensor (THPH-S)
- Temp/Pressure/Humidity Sensor (BME 688)
- Ambient Light Sensor (VEML 7700)
- Current Sensor (INA 219)
- CO2 Sensor (U21000001)
- Off Gassing MQ Sensors
  - MQ-8 Hydrogen
  - MQ-4 Methane
  - MQ-135 Air Quality
  - MQ-7B Carbon Monoxide

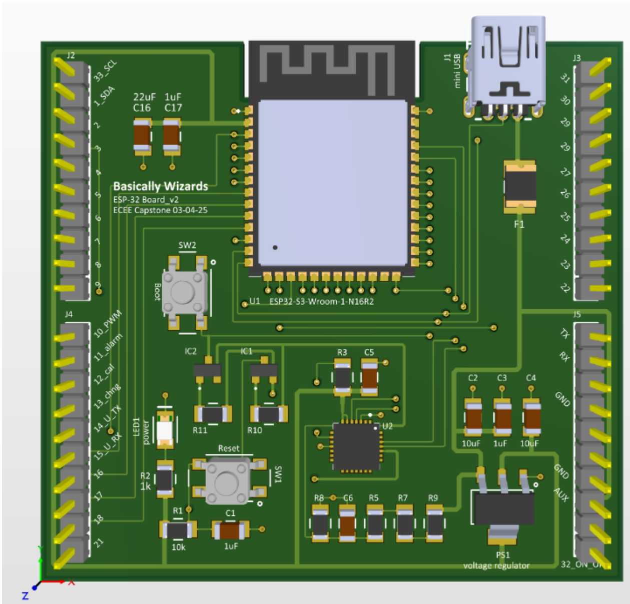
API

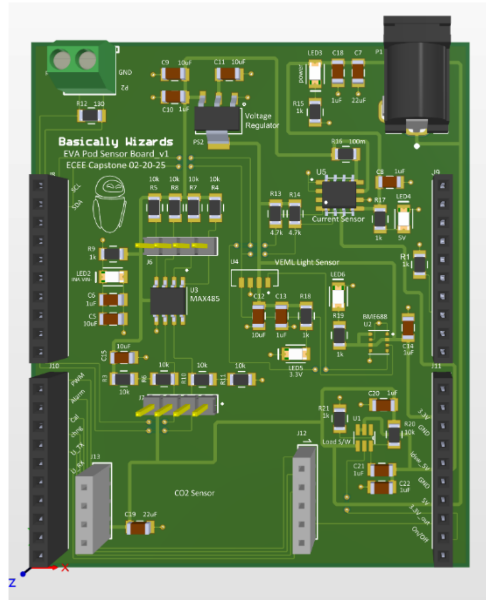
- Google Maps API
  - Selected due to high customizability and familiarity with the anticipated customer base.

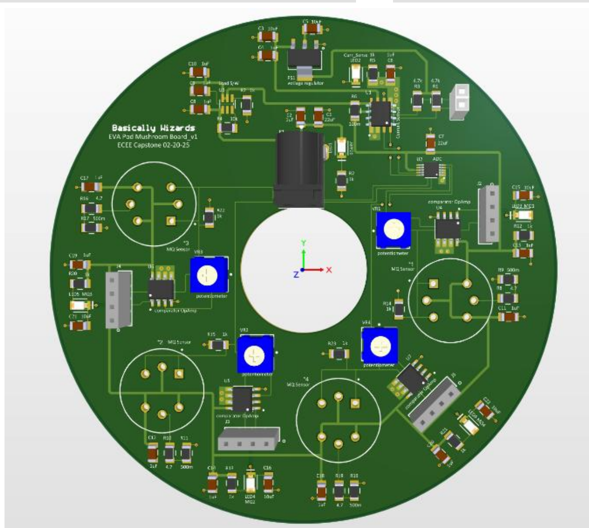
Other Components

- 5V 8AH Batteries
- ABS 3D Print Filament
- Velcro Strap for mounting
- Raspberry Pi
  - For hosting our web server and storing the collected data

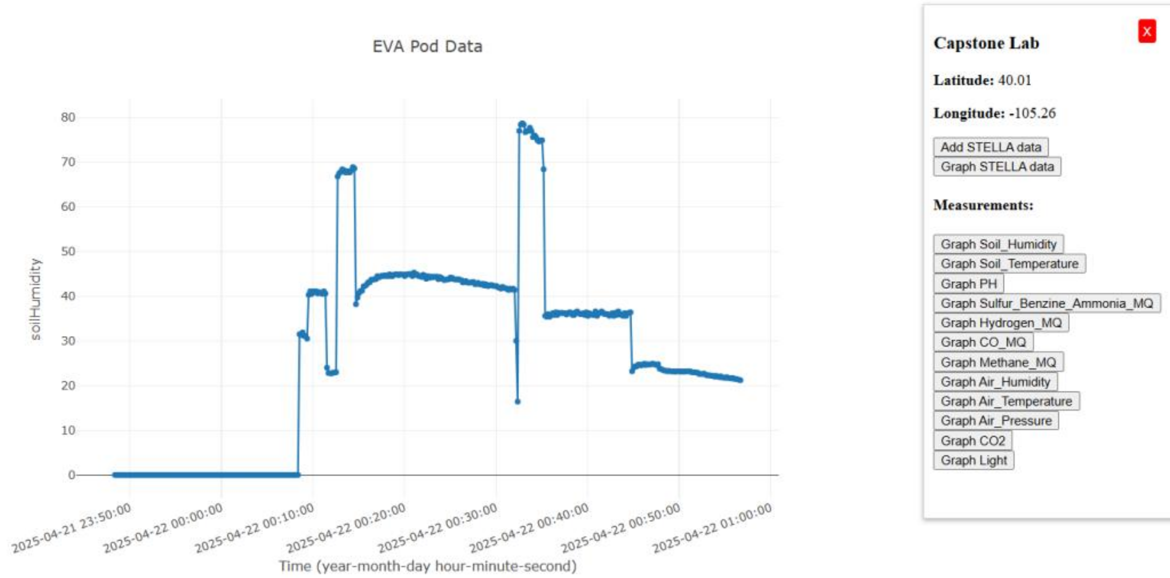
Printed Circuit Boards



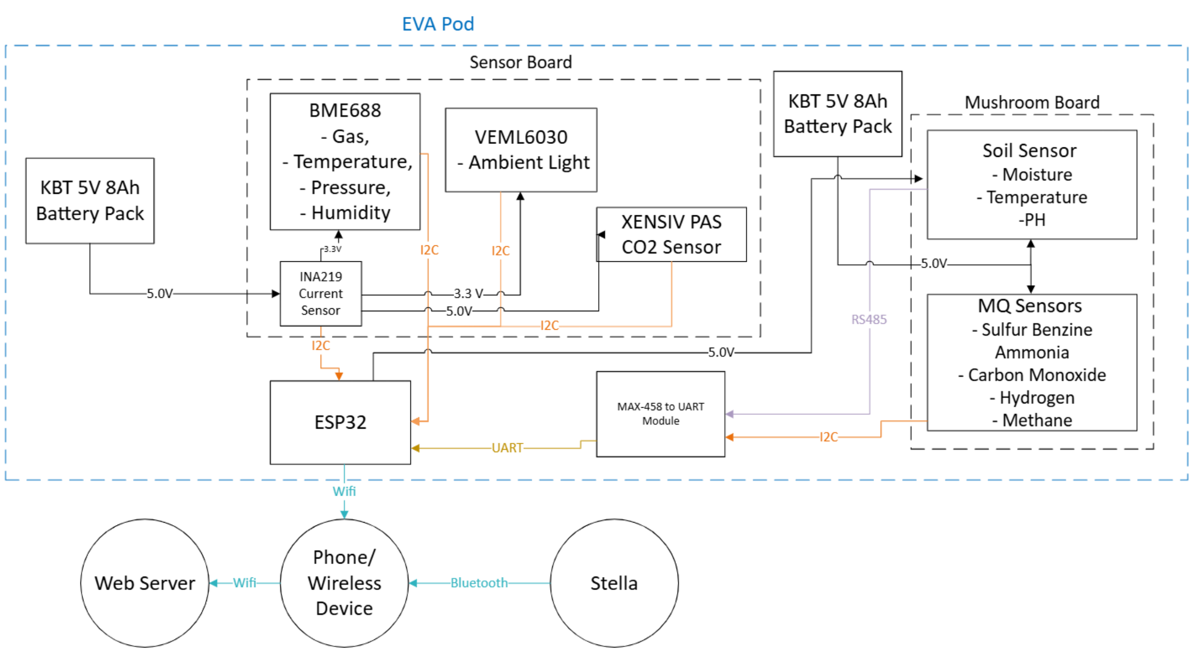




Website



Functional Block Diagram



How does it work?

The EVA Pod contains a suite of commercial sensors that take environmental data from the air and soil, and an ESP32 which periodically wakes up, reads from each sensor, and then goes back to sleep to save battery life. The data is stored in a csv file in the flash memory of the microcontroller. The microcontroller can also host a wifi server which allows the user to communicate with the EVA Pod wirelessly. The user should connect once, when setting up the pod, to provide a timestamp and location data to the EVA Pod and then can connect again at the end of the collection period to download the file and clear the data.

The EVA Pod consists of two physical modules, one that is mounted to a tree and one that is planted in the ground. Each module has its own battery. The two modules are wired together so that all of the sensors can share the ESP32. The ESP32 communicates with most sensors via I2C, except for the commercial 3-in-1 prong soil sensor, which requires the MAX483-UART converter to talk to the microcontroller. The optional ground module (the MOSS) holds this commercial soil sensor for sensing pH, temperature, and moisture of the soil, and a variety of MQ gas sensors in the cap of the mushroom, which detect gases coming up from the ground. The voltages from the MQ sensors are converted into digital values before being sent across the wire connecting the modules.

The EVA Pod functions without Internet so that it may operate anywhere. The user can download the data to their personal device and carry it out of the field site. The user can then upload the data to the EVA Online website when they are able to access it. The website also optionally supports spectrometry data from the NASA STELLA so that students working on this project can see both datasets together.

Analysis

What worked

The EVA Pod successfully reads timestamped and geotagged data from each of the commercial sensors, and turns itself off between measurements to conserve battery. We did not have time to perform our full 2-week battery tests, but our measurements of the current drawn indicate that the EVA Pod will operate for 30 days before draining the EVA battery, and 6 days before draining the MOSS battery. At EXPO, we had the MOSS run off of battery while streaming data live, and it lasted for the entire duration of the event.

Both EVA Pod enclosures were successfully weatherproofed from moisture incident from the top and sides. Our only recommendation related to weatherproofing is to not leave the MOSS out where it might be submerged. The EVA Pod enclosures were also successfully made to be simple, small, and require limited tools, to support our goal of making a user-friendly, easy-to-install product.

The EVA Pod successfully stores the data in nonvolatile memory, so that users can still retrieve it after power loss. It also sends the data to the user, in the exact format that is required by our website. EVA Online successfully parses this data for storage and plotting, and displays each stored pod on the map. EVA Online can also take in STELLA spectrometry data associated with the EVA Pod and store/display it. However, this works based on a preliminary example file that we received, and may need to be updated to be compatible with the new STELLA that is in development now.

What did not work

We had a number of issues, but the top 3 were the final versions of our PCB's, creating a global access point to the website, and having sensors that were not 100% effective.

1) **PCBs**
   Our PCBs went through 3 iterations in total, and our final design had dozens of hours poured into it. However, our team made a few key assumptions each iteration that punished us later on. In the first iteration, we didn't add a UART bridge so that we could debug the ESP32 S3. This problem was solved by our final iteration, but because we couldn't debug the ESP32-S3 until our final iteration, we didn't learn that our footprint for the ESP32-S3 was correct, but our Schematic for it was not. The assumption that our schematic was correct, without putting the 20 minutes necessary in to checking that cost us over 20 hours later on rerouting pins and reprogramming the shield so that we could properly communicate with the sensor PCB and actually read the data out. In future, a new PCB, with the correct file for the ESP32-S3 would need to be created, with the same form factor as the current one.

2) **Website Access**

Currently, our website is hosted on a local server and accessed only when connecting to the Capstone Wi-Fi. This is because we did not make the time or effort to get it hosted in a format that was accessible on any Wi-Fi network. This is a problem, because it removes the functionality of accessing global data about the pods. An important feature of the project is that users are able to collect data and push it to an interconnected web of data that is accessible to everyone. This is sadly impossible to do without both significant work on the backend of the website and the use of a service which would host the website globally, such as cloudflare.

3) **Sensors**

Sensors were a problem for us throughout the semester, because finding sensors that can properly collect soil data is nearly impossible. Our solution was to use the best sensors we could find for our affordability, the MQ sensors. But offgassing is unreliable at best and completely pointless at worst, as getting accurate off gassing measurements would require us to create a far more enclosed and controlled system than we have. Some network of fans, valves and sensors would be able to accurately and effectively measure the data, but that was outside of our power, time and potentially even our financial budget. We have done the best we could at the price we are at, but in future, a redesign of the mushroom to improve data quality would be highly valuable if not necessary.

So what?

Over the course of this project, the team has gained a number of technical, professional, and interpersonal skills while planning and developing our product. These takeaways are summarized below.

Technical

- Printed Circuit Board (PCB) design
  - Get as many eyes on a board before ordering it as possible
- Web development (HTML/CSS/JavaScript)
  - Using GitHub to collaborate on this and merge our work
- Web server hosting on RaspberryPi
- Computer Aided Design (CAD)
- Iterating designs

Professional

- Long term project planning
- Risk management and creating backup plans
- Writing and performing tests
  - It is important to know what you expect because if you get completely unexpected values, you know that there is a cause that must be troubleshot. This is what we learned in our power test from the first semester, because the current we measured was so high that we determined we had a bug in the sleep code.
- Project pivoting as required
  - If something is not going to work, another course of action must be taken (or at least tried), such as our switch from the commercial soil nutrient sensor to the MOSS.
- Presenting to technical and non-technical audiences

Interpersonal

- Dividing into subteams based on strengths and interests
- Communicating across subteams to ensure components integrate
  - For examples, making sure that the PCBs would fit in the enclosures and that the website would read the EVA Pod files.
- Reviewing one another's work

Conclusion

In the end we succeeded in creating a product that was user friendly, easy to produce and provides consistent accurate data about the environment. While the version we presented at expo was nowhere near a true finished product and would require another version of the PCBs and some adjustments to the way we handle assembly we are confident that what we made would be accessible to the sustainable farmers, space grant teams and any backyard scientist who wants to learn more about their environment.

Team Reflections

Julia DiTomas

I had a lot of fun throughout the whole year of Capstone, especially during EXPO, where a lot of guests told us how cool our project is, and how they or somebody they know would love one. Other highlights were being in class and getting to chat with everyone about project and non-project topics, and getting to come up with ideas and fix issues together. The low points were the occasional late nights in which it seemed like things were never going to work. If I were to do this project again, I would, instead of migrating towards tasks that required my existent skills, ask to do work unknown to me that would provide me with new skills. But I did grow a lot as a person and an engineer. This was the most complex team project which I have ever completed, and I learned a lot about communicating with my team members and those outside of our team. I also learned how to get started on something, when you only have an idea and don't really know where to start or who to turn to.

Anika Mathur

Overall, I had a lot of fun throughout the year in capstone. At the start of this year, I knew very few people walking into capstone and was worried about the outcome of team dynamics and working in a team for an entire year. However, after meeting my team of very bright and talented individuals, my worries began to disappear. Our project brought challenges and helped me grow as an engineer in my technical skills. This project was the first I had worked on to this scale with the amount of technical responsibilities I held. Additionally, it provided avenues to learn skills as the project progressed and apply many skills I had learned in my ECEE classes over the last couple of year. On top of gaining more technical knowledge and experience, I also grew as a communicator inside and outside my team. Having a project where you had to create your own scope and then make changes to that scope along the way was a very insightful learning experience that gives a good view into the industry world when starting new projects. Overall, I truly enjoyed my capstone experience and will apply the skills I learned to my professional career.

Shane McCammon

I really enjoyed my Capstone experience. I had the privilege of working with a group of very bright and capable students and was able to learn a lot from all of them throughout our time working on our project. This team was great to work with and there were never any problems we weren't able to eventually solve. There were many late nights and the occasional stress of meeting deadlines, but I had a lot of fun rediscovering my creativity by having actual hands-on tasks and a laboratory with many great tools at my disposal. Making cool and interesting things while exploring new and unknown ideas is what drives me, and this project allowed me to do exactly that with the help of a lot of great people. There are many positive takeaways from this experience that I will continue to carry with me throughout my professional career and everyday life.

Sydney Medina

I think the most valuable thing I gained from Capstone was working with a great team. Never have I had the pleasure and fortune to work with a group of such compatible and capable individuals. It taught me to be able to trust my team with their own commitments and to lean on them in areas I am weak in. A high of Capstone was most certainly having a beautiful, intriguing final project and the EXPO experience (minus the long duration and glaring lights). If I had to do the project again, I would have liked to have already had the PCB class under my belt and would have absolutely loved to have helped develop the boards. In the future, I think I will approach team projects with open enthusiasm rather than my previous jaded outlook. There is a huge difference between a group a freshman doing a project and a group of competent seniors, and Capstone showed me that a great team really can exist and be wonderful.

Andrew Morris

Capstone has been a once in a lifetime experience. I have developed multiple projects and products before, in other project classes (4 in my college career), and overall, this has been both the most intensive and the most effective. I got to work on something, from the ground up with my teammates, and create a product that was truly ours, rather than a reorganization of things we found online. It was hard but it worked in the end, and I am grateful to have had an amazing team. In future, I will be moving away from the technical components of engineering, as I am going into the legal field, but I will always remember and use rule #9 when coming at problems, both inside and outside of engineering.

Eli Wall

I enjoyed my capstone experience thoroughly, though it was awkward at times to balance the stresses of my personal work and ensuring that everything was still on track to be finished by expo, it was still an overall positive experience. I learned how to trust others to do work well, on their own, without micromanagement and honed my ability to troubleshoot or debug problems. Going into it I had hoped to work with novel technology as a part of an industry team but the challenges of setting our own requirements and scoping the project properly ended up being just as daunting of a problem. The way I tackle problems has changed as a result of this course and more importantly than anything else, I learned how to keep working until it is working.

Environmental Sensor Pod (EVA Pod)

Julia DiTomas, Andrew Morris, Anika Mathur, Shane McCammon, Sydney Medina, Eli Wall

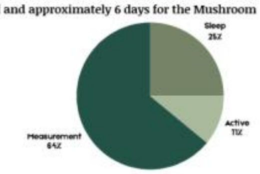
Product Overview

The NASA EVA Pod has two modules associated with it: the EVA Pod and a mushroom-shaped off-gassing and soil sensor.

- Sensors utilized in the EVA
  - Temperature, Humidity, Pressure, and Gas (BME688)
  - Light (VEML 7700)
  - Current (INA219)
  - CO2 (U21000001)
  - RS485Max Transceiver Chip Module
- Sensors utilized in the Mushroom
  - 3-in-1 Soil Sensor (THPH-S)
  - 4 Gas Sensors: MQ-8 Hydrogen, MQ-4 Methane, MQ-135 Air Quality, and MQ-7B Carbon Monoxide
- Each module has its own 5V 8AH Li-ion battery

Power Budget

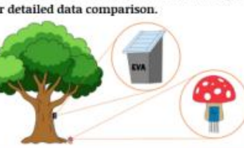
- EVA Pod is collecting data 6 times a day
- Gas sensors are running for 5 minutes every 24 hours
- Battery Life Estimate: Estimated to last 31 days for the EVA Pod and approximately 6 days for the Mushroom

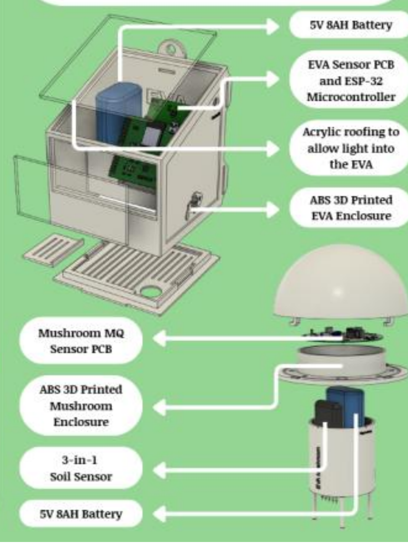


Data Flow

Objective

The NASA EVA Pod is designed to autonomously collect environmental data over several weeks, providing comprehensive background information. It works in tandem with the NASA STELLA Module, a hand-held device used to capture key environmental measurements during field visits, allowing for detailed data comparison.

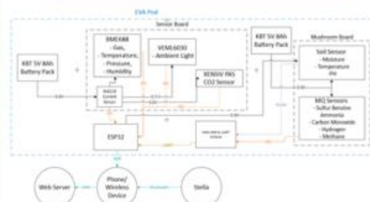




User Interface

- Data Display Website:
  - Uses a Google Maps API to upload EVA Pod and NASA STELLA results to a shared website.
  - Allows comparison of STELLA's hand-collected data with EVA Pod data.
  - Supports Latitude and Longitude inputs to visually map which STELLAs correspond to specific EVA Pods.

System Diagram



Acknowledgements

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