Team 12: Particulate Matter Sensor Node

Department of Electrical and Computer Engineering

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Overview

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Problem Statement

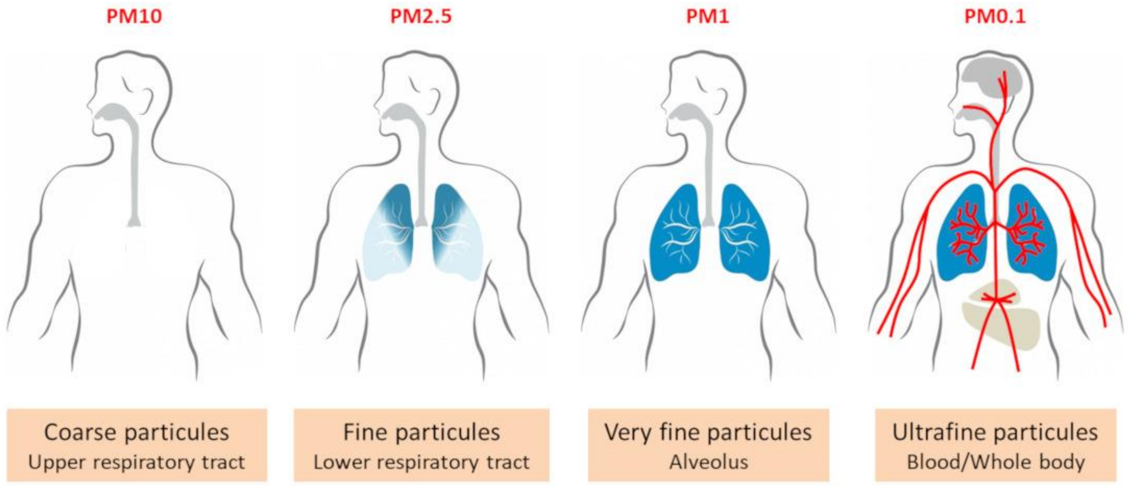
Problem Overview

What is Particulate Matter

- Common air pollutant
- Solid and liquid particles
- PM, PM1.0, PM2.5 and PM10
- Composed of **smoke, dust, soot, salts, acids, and metals**

Impacts of Particulate Matter

- **Numerous health issues**
  - Nonfatal heart attacks
  - Decreased lung function
  - Increased respiratory symptoms
  - **Premature death**



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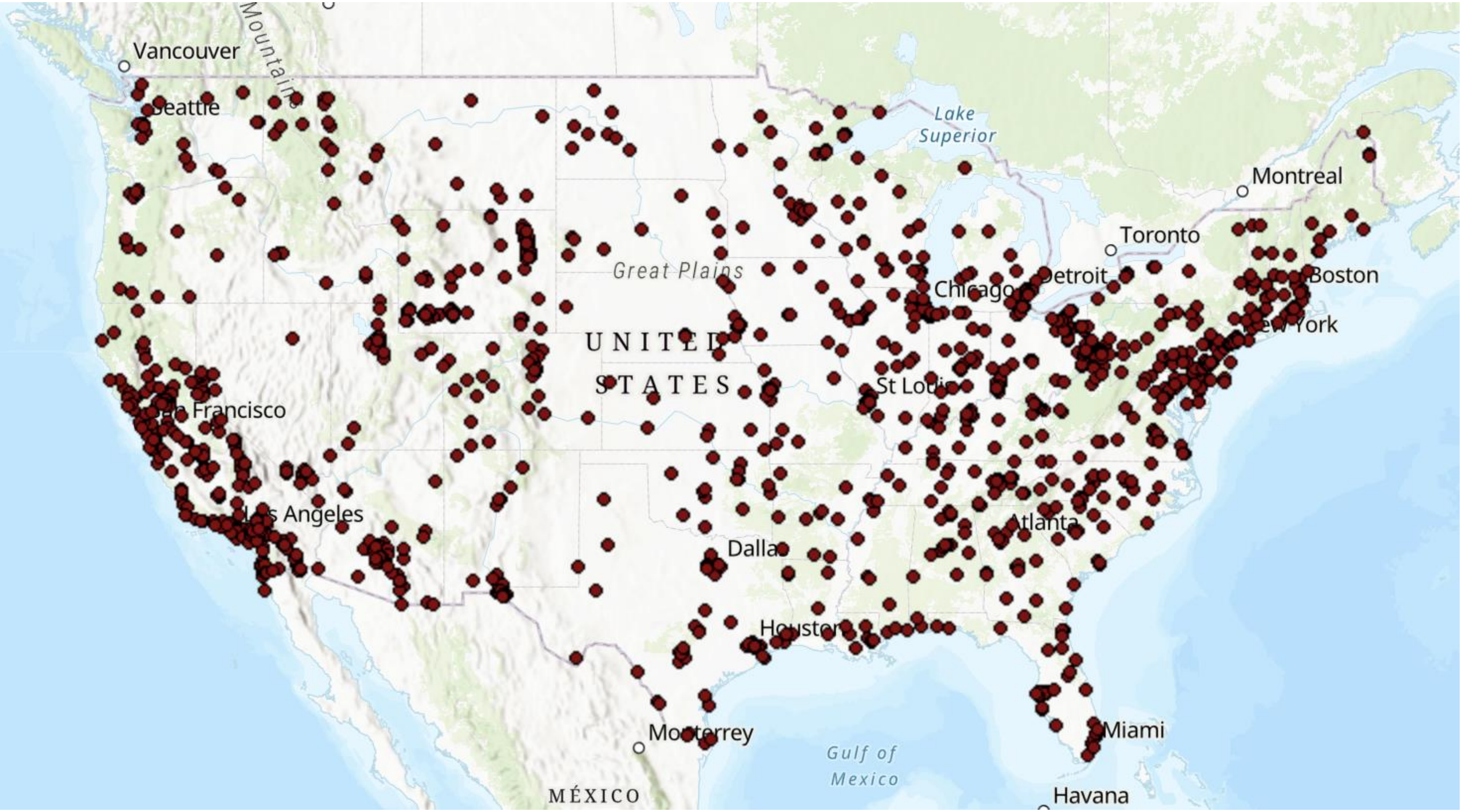
Problem Overview

Issues With Current Methods of Measuring Particulate Matter

Issues	Granular Data	External Resources Reliant	Price
Overview	• **Large** radius collection • Several large areas (100 mile radius) with **no PM data**	• Reliant on external networks and power sources • External Networks **transmit weather data** to web servers	• Low-end weather stations **don't** include PM sensors • Stations with PM sensors, are often **significantly** more expensive

Map Overview



Project Overview

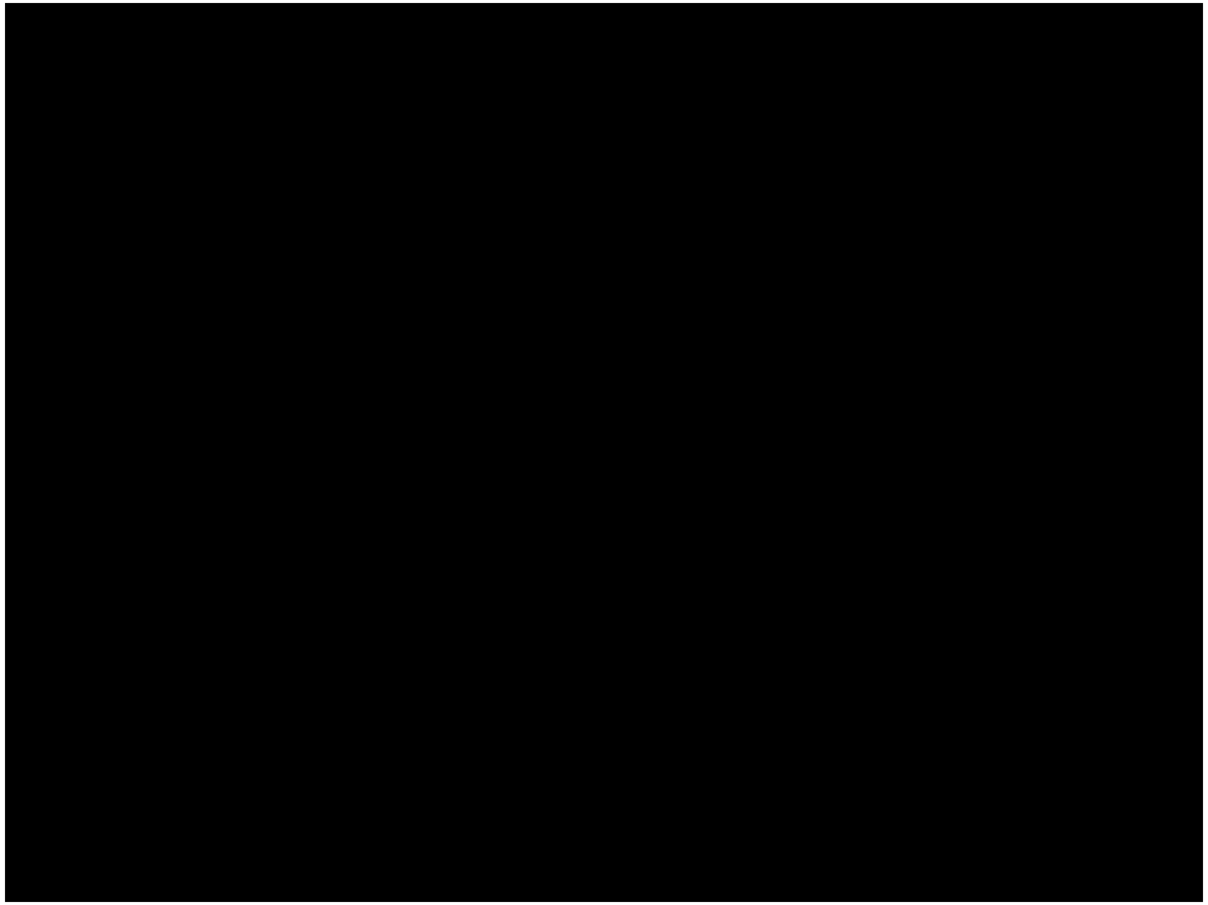
Project Overview

A System To Address The Constraints Of The Current Systems

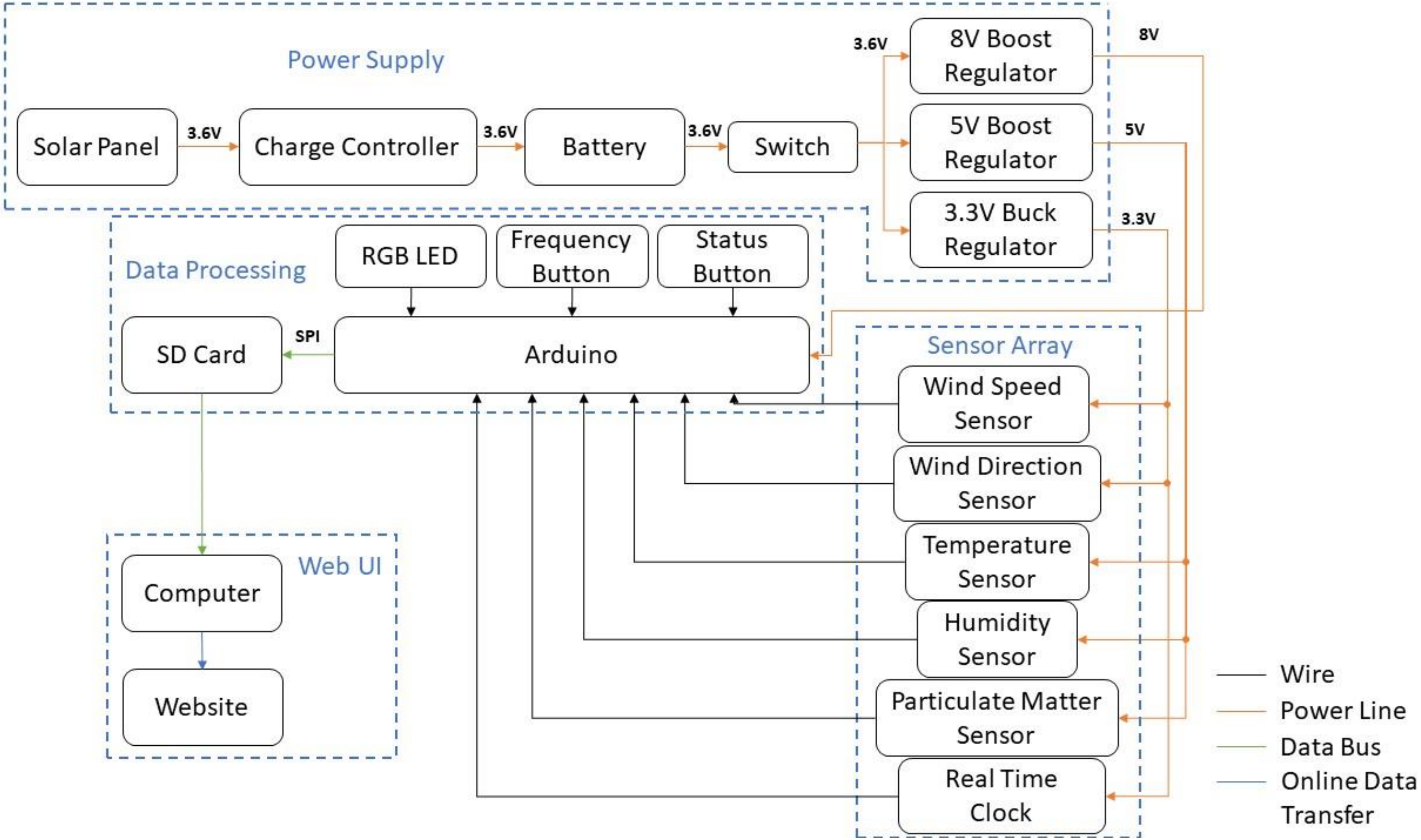
Improvement	Overview	End Goal
Autonomous	• **Solar powered battery** to power our system • **On-device memory** to store PM data	Collect PM data without the need of user oversight
Mobile	• Physical enclosure that allows our system to be **mobile** and **deployable**	Help collect PM in hard to reach areas
Affordable	• Remove sensors that don’t assist in PM data measurement (e.g. rain sensors)	A affordable system will allow scalability for the EPA

Design Overview

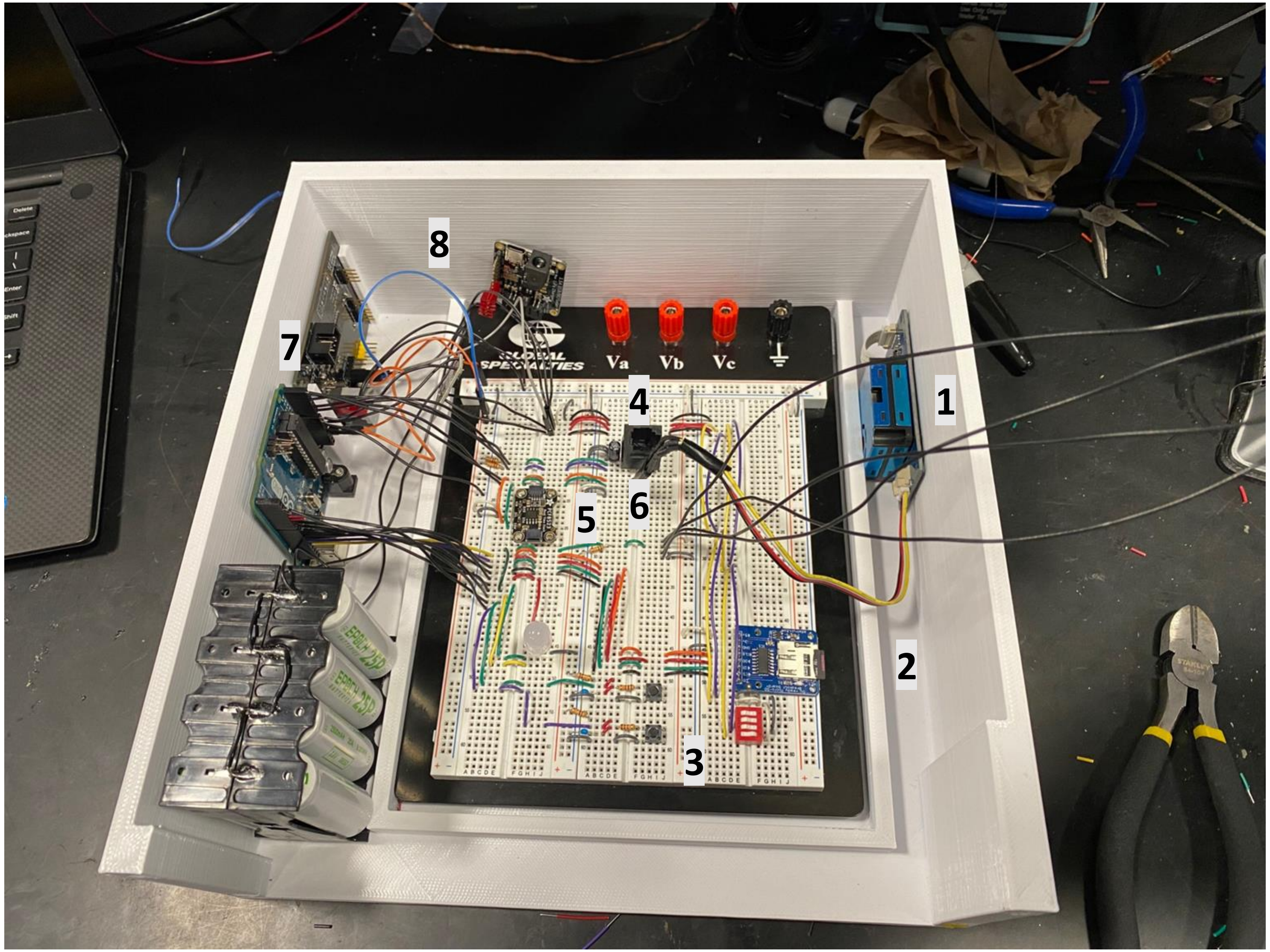
Physical Design



Block Diagram



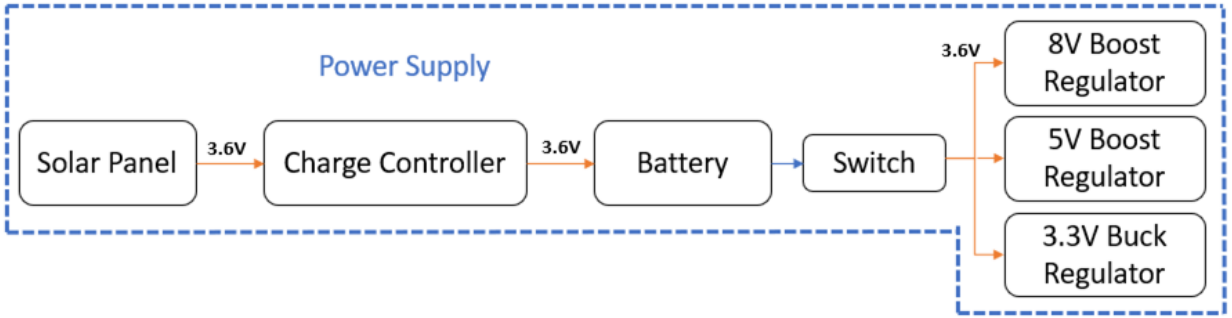
Physical Design



1. PM Sensor
2. SD Card
3. Control Panel
4. Wind Sensor
5. RTC
6. Temperature Sensor
7. Microcontroller
8. Power Supply

Subsystem 1 - Power

Power Subsystem Overview



Component	Solar Panel	Charge Controller	Battery	Voltage Regulators
Overview	• 6 Watts • 19% efficiency • Produces 168 - 749 Wh/month • **Extends battery life**	• Charges batteries from solar panel • Prevents overcharging and overdraining • Uses **solar power over batteries** when possible	• **Modular** 20 Ah battery pack • Eight 2500 mAh **rechargeable lithium ion** cells • Produces 3.6V	• Switching regulators are up to **90% efficient** • Converts the battery voltage to 3.3V, 5V, and 8V

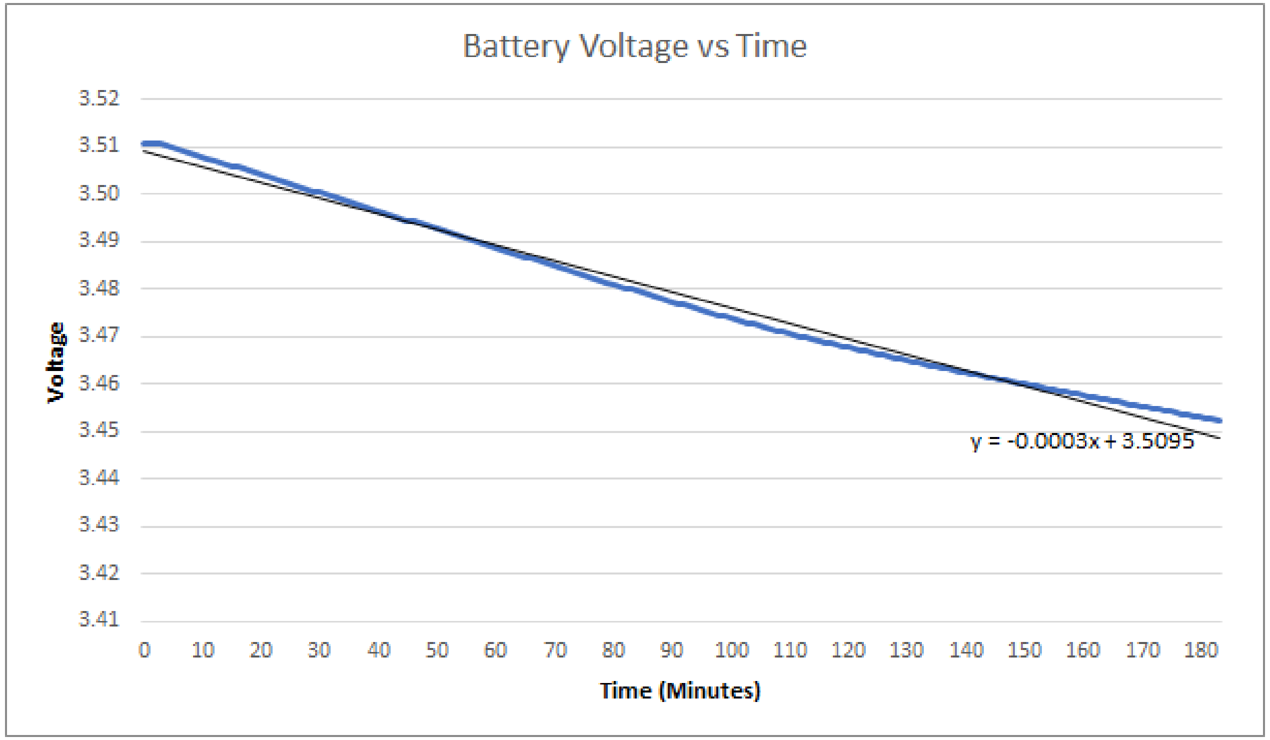
Power Verification

Requirements and Testing Plan

- Must be able to supply power to the sensor node for **one month** at all frequencies
- Tested battery life by characterizing battery voltage during operation

Results (**Failure**)

Battery Percentage	Voltage	Time (Days)
100%	3.6	0
90%	3.5	0.22
80%	3.4	0.44
70%	3.3	0.65
60%	3.2	0.87
50%	3.1	1.09
40%	3	1.31
30%	2.9	1.52
20%	2.8	1.74
10%	2.7	1.96
0%	2.6	2.18



Subsystem 2 - Sensor Array

Sensor Array Overview

PM

- Collects PM1.0, PM2.5, and PM10
- Communicates via I²C bus

Temperature

- Collects temperature data in degrees Fahrenheit
- Communicates via a digital signal

Humidity

- Collects humidity
- Communicates via a digital signal

Wind Speed

- Collects wind speed in miles per hour
- Communicates via an analog signal

Wind Direction

- Collects wind direction
- Communicates via an analog signal

RTC

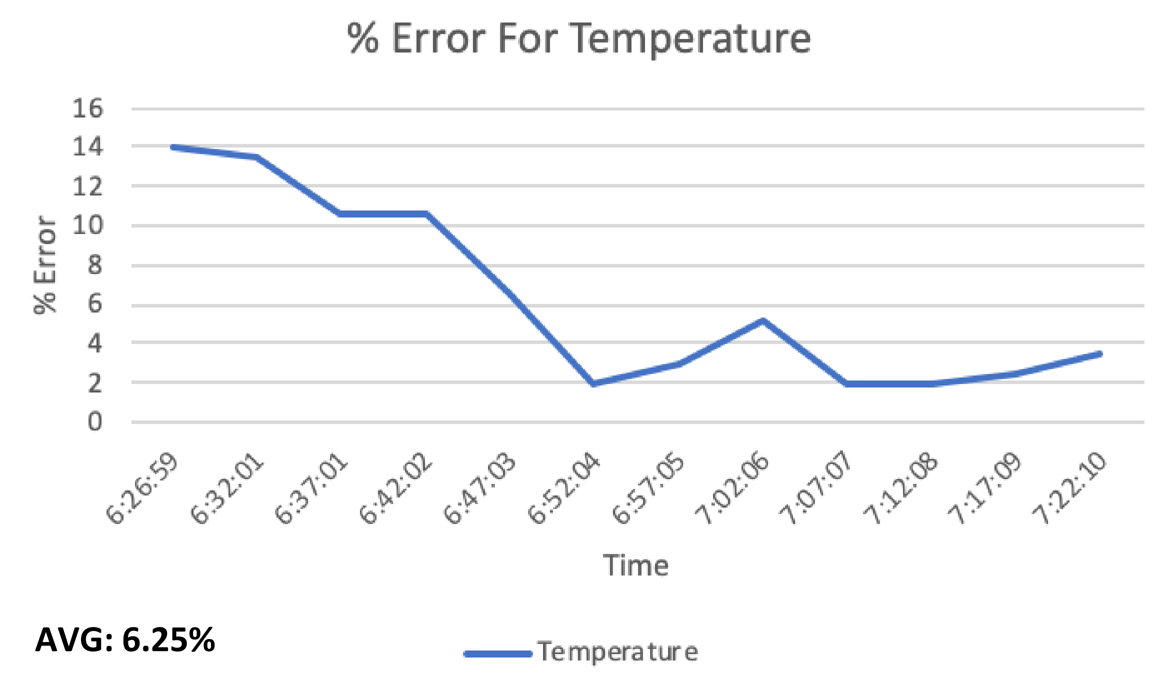
- Collects the real time
- Communicates via I²C bus

Sensor Array Verification

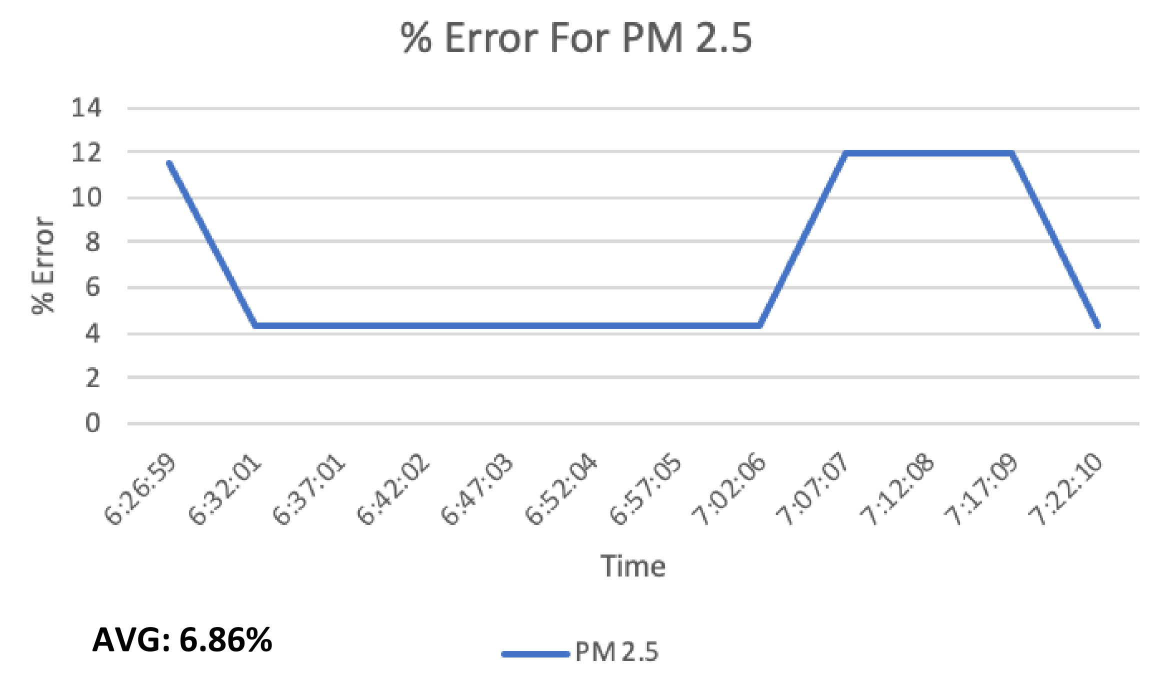
Requirements and Testing Plan

- Sensor array is within **10% of truth value**
- Tested our system at CMI airport for one hour at a 5 min write frequency

Results



AVG: 6.25%



AVG: 6.86%

Subsystem 3 - Data Processing

Data Processing Overview

The connective tissue for our system

Features	Data Storage	Write Frequency	Sensor Status
Overview	• Communicates to sensors via GPIOs • Writing sensor data to a on-system SD card	• 3 write frequency, 5 minute, 1 hour, or 3 hour interval. • Changes the write frequency via control panel	• Relays each sensors status to a user via RGB LED • Each Sensor has its own RGB value

Design Pivot

Proposed design

Sensor Array → Atmega328-AU → On-device Memory

Atmega328-AU Roadblock

Root Cause of Microcontoller Failure

- Atmega328-AU can both bootload and upload code
- Uploaded code would not execute
- The internal 8 MHz oscillator crystal has a **10% inaccuracy**
- This accuracy impact UART communication protocol

New design to address roadblocks

Sensor Array → Arduino Uno → On-device Memory

Data Processing Verification

Verification testing for data processing subsystem

Requirement	Test overview	End Result
Needs to be able to store **30 days** worth of air data	Calculate the number bytes needed to store data in a .txt file by the fastest write frequency (5 minutes)	• **Passed**, the largest memory size is 8640 rows of data at 72 bytes ~.622 mb
Writes to SD card on a **5 minute, 1 hour, or 3** hours intervals	For each frequency setting, collect data for 24 hours	• **Passed**, each write frequency wrote to memory at the correct interval for of 24 hours
Control panel displays the LED value within **0.5 seconds**	Time pressing a button and the LED response	• **Passed** for status button • Displayed correct error signals

Subsystem 4 - Web UI

Web UI Overview

Present the particulate matter data in a more actionable way

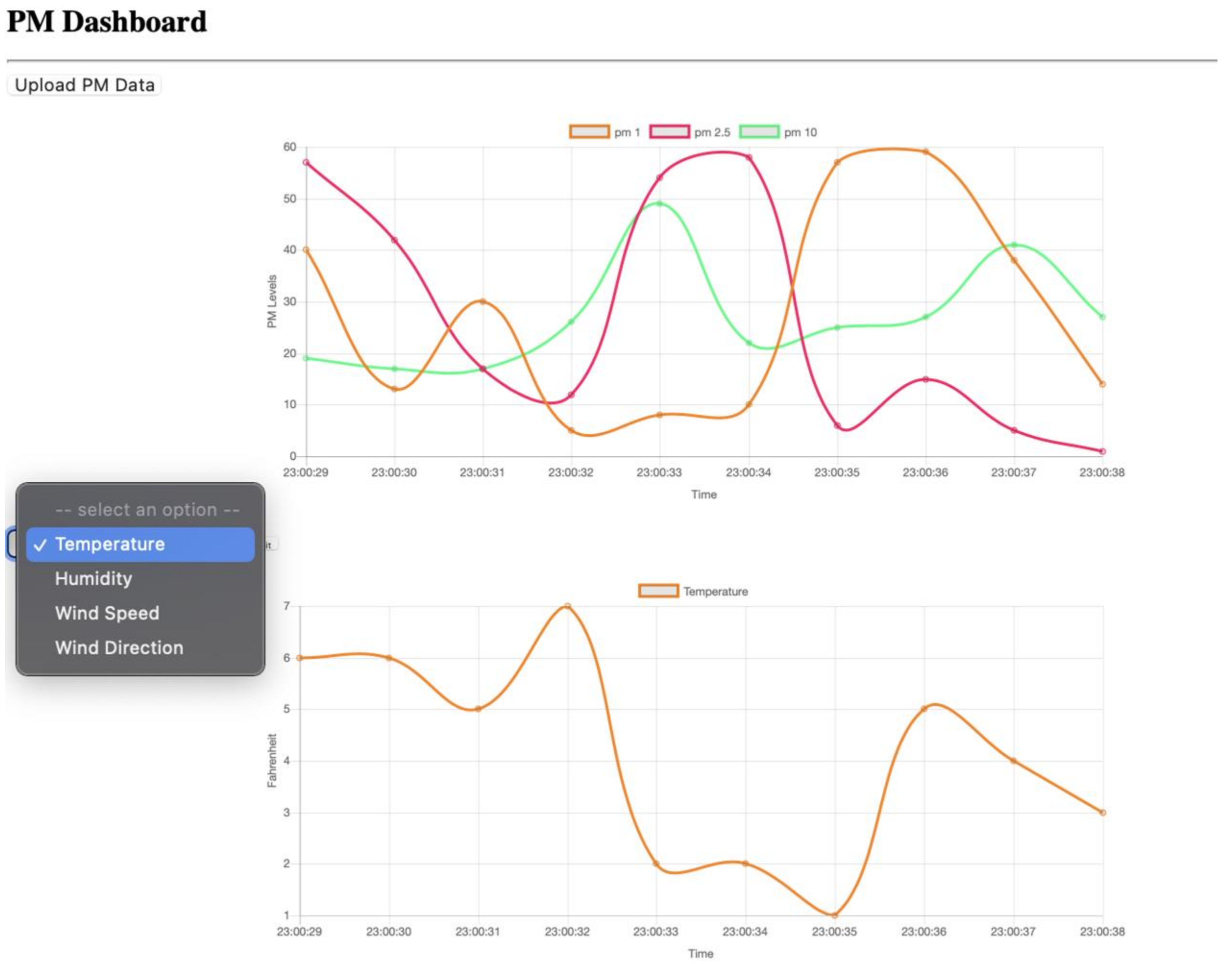
Key Features

Intractability

- **Powerful way** of deriving insights from the data
- Upload the raw file to the web UI to **compute visualization**

Technologies

- Python for backend functions
- HTML/Javascript for frontend
- MySQL on GCP for data storage



Web UI Verification

Web UI Requirements and Testing Plan

- Website parses and displays data within **10 seconds** of an upload
- Tested parsing algorithm on 3 distinct datasets (8640 rows)

Results of Web UI Verification Testing

```
mahip@Omega PM-Dashboard % python parser.py
Parsed 8641 rows of data.
('total time to parse data was:', 3.0315780639648438)
mahip@Omega PM-Dashboard % x
```

```
mahip@Omega PM-Dashboard % python parser.py
Parsed 8641 rows of data.
('total time to parse data was:', 3.454921007156372)
```

```
mahip@Omega PM-Dashboard % python parser.py
Parsed 8641 rows of data.
('total time to parse data was:', 3.4079501628875732)
```

Final Thoughts

Future Work

Phase 1
Improve PCB

- 16 Mhz crystal oscillator
- Low power mode
  - Sensors
  - Microcontroller

Phase 2
Improve Physical Design

- Weatherproofing
- User accessibility
  - Sensor placement
  - Button placement
  - Compartment doors

Phase 3
Add User Interface

- LCD Screen
- Ease of data transfer

Questions

Appendix

Ethical Concerns

Ethical Concern	Over Heating	Box Placement	Data Bias
Overview	Rechargeable battery could potentially overheat and pose a fire risk	Our system could be placed in private property without prior approval	Data collected by our device may introduce bias about sources of PM

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