Miniature Multi-Sensor Array (mini-MSA) for Ground-to-Stratosphere Air Measurement, Phase II.

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Introduction & Background

There are numerous college research groups doing high altitude ballooning and working with drones. Many of these are making air quality measurements. Those measurements are effectively random. We are designing an inexpensive and easy to build assembly that others can build for under $500 with the goal of having a uniform data set that can be compared. This will provide more useful data for atmospheric studies. Our first version had too many noise issues and the gas sensor signals were unstable. In December 2020 Winsen Sensors (China) came out with a "multi-in-one sensor module," the ZPHS01B. At a price point of approximately $150 we decided to completely revise our design.

Introducing the miniature Multi-Sensor Array ("miniMSA") version 2.0!

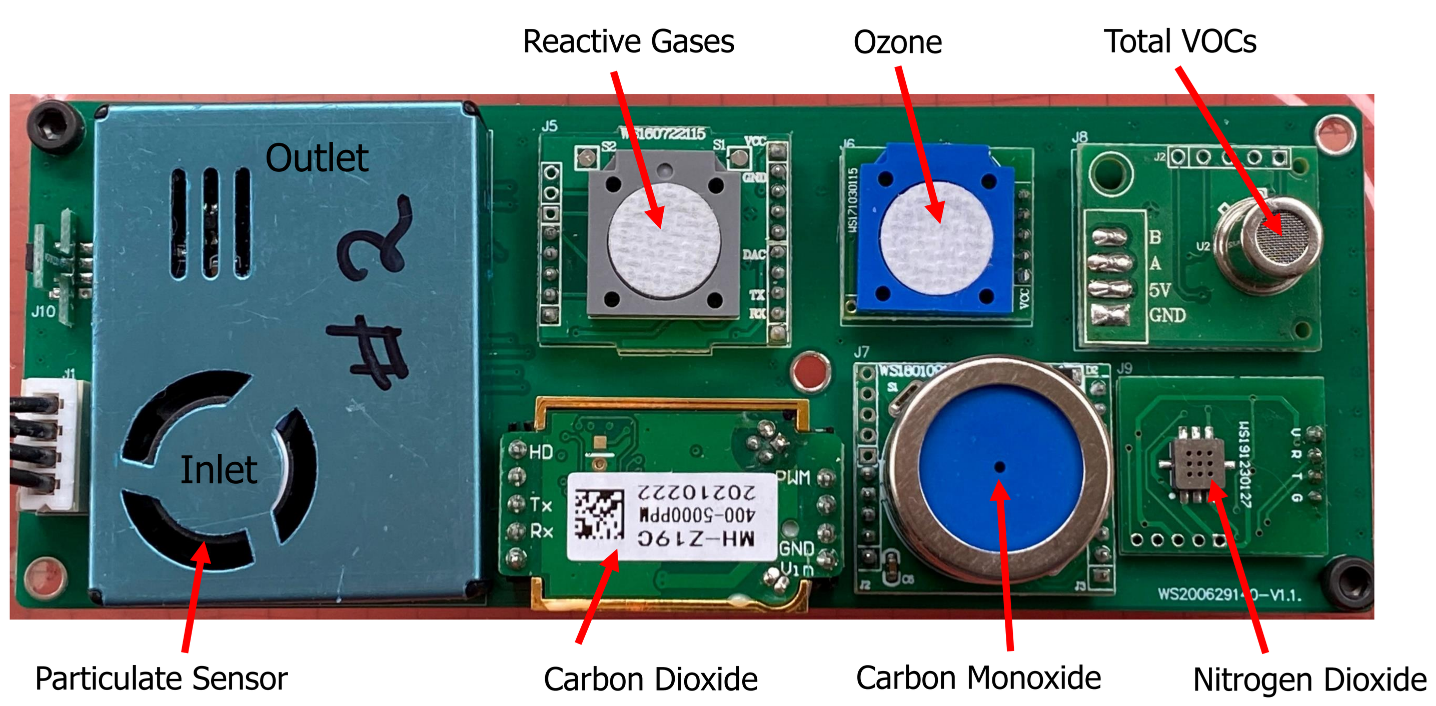

Figure 1. The Winsen brand ZPHS01B sensor module. This module measures: PM1.0, PM2.5, PM10, CO, CO_2, Reactive gases (formaldehyde, alcohols, sulfur dioxide, hydrogen gases, etc.), Total VOC, O_3, and NO_2. The Temtop PM-900M particle sensor is similar to the common Plantower PMS7003M.

Design Overview

Version 2.0: Raspberry Pi based version.

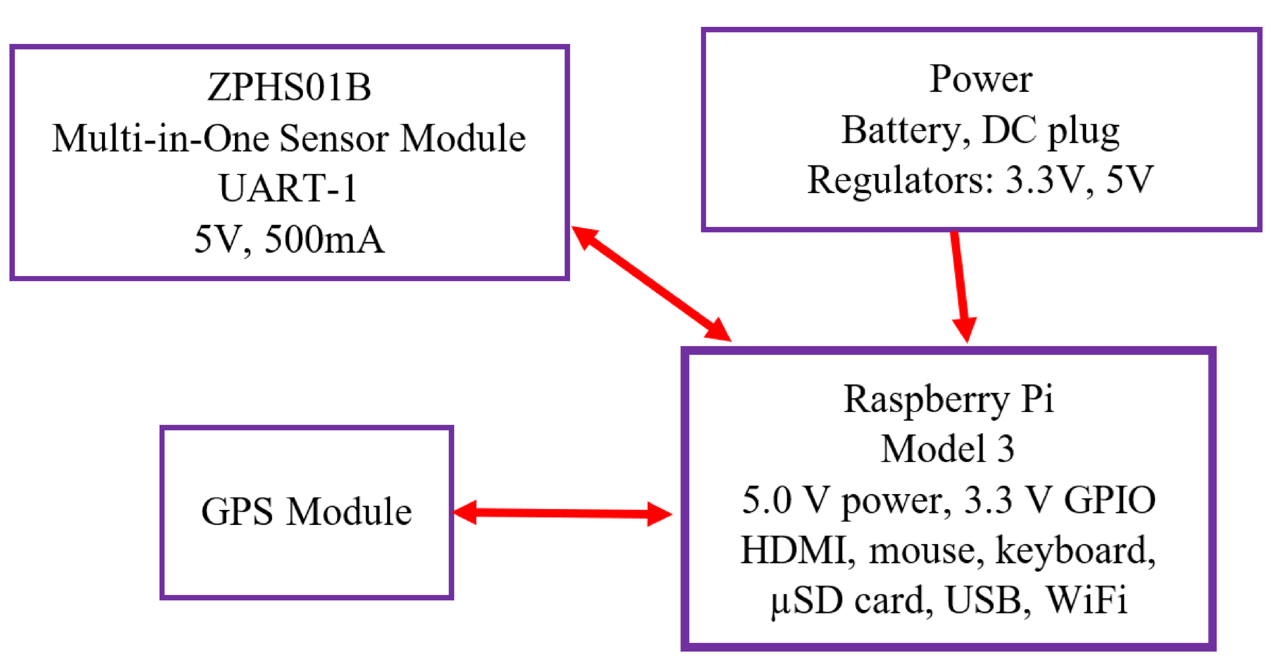

Figure 2. Block diagram of the system. The Raspberry Pi is probably not the best platform. The RPi clock is unstable, the data storage is hard to access, and it doesn't like having the power pulled. We solved most of these problems with the GPS and using the RPi as a web sever to push a webpage that you can use to control the MSA from a laptop or phone. An Arduino with a thumb drive might be a better platform or a custom microcontroller system.

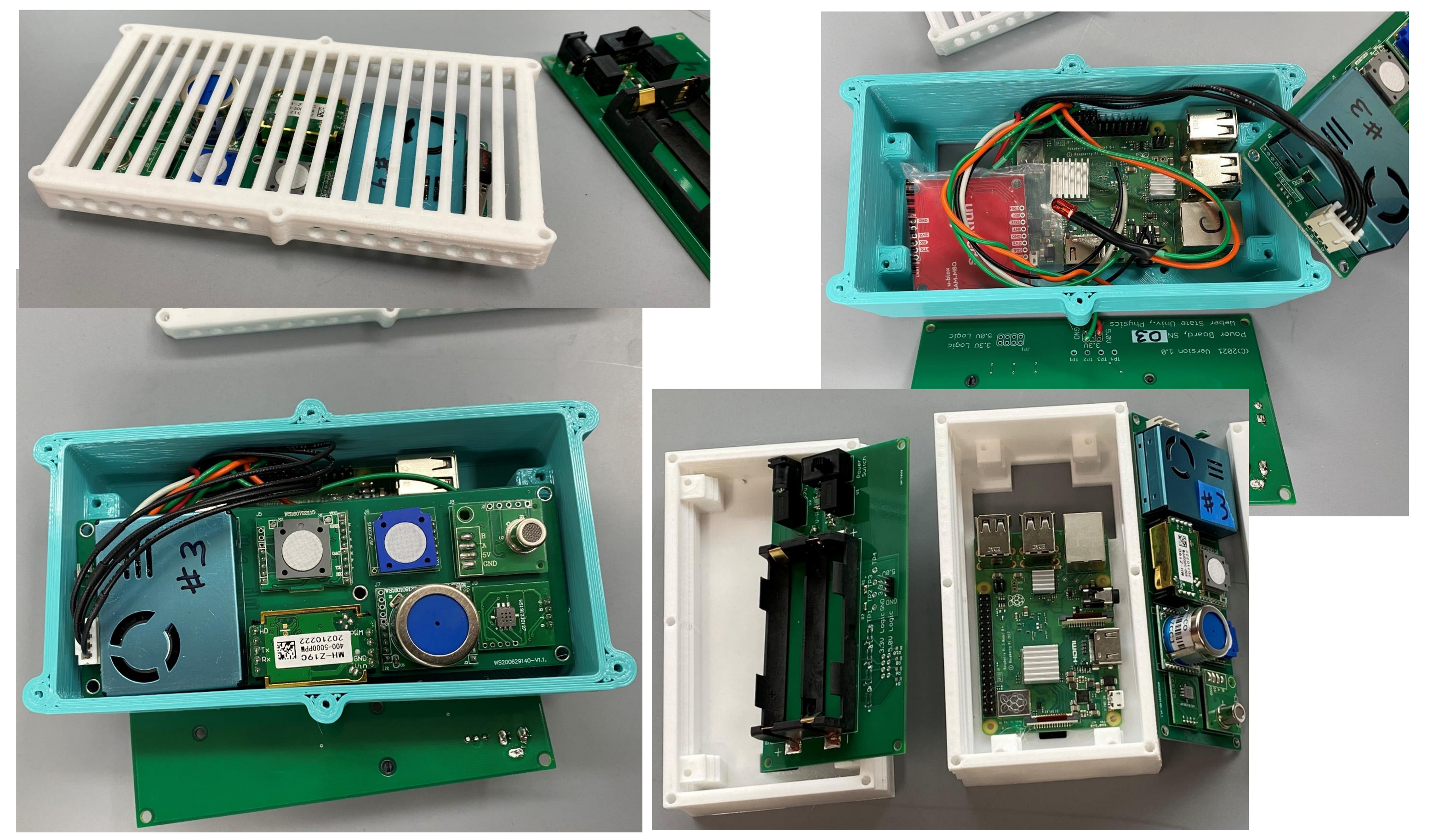

Figure 3. Prototype housing design showing various stages of assembly-disassembly.

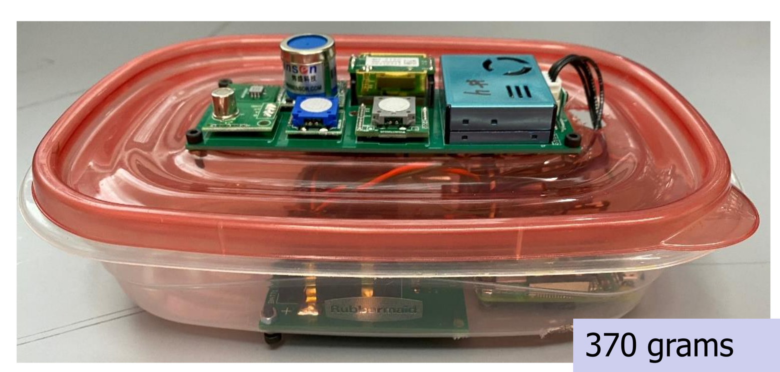

Figure 4. The temporary housing, a Rubbermaid sandwich box) works well for now. Shown in detail above and under a drone on the right.

Winsen Sensor Performance (not very uniform)

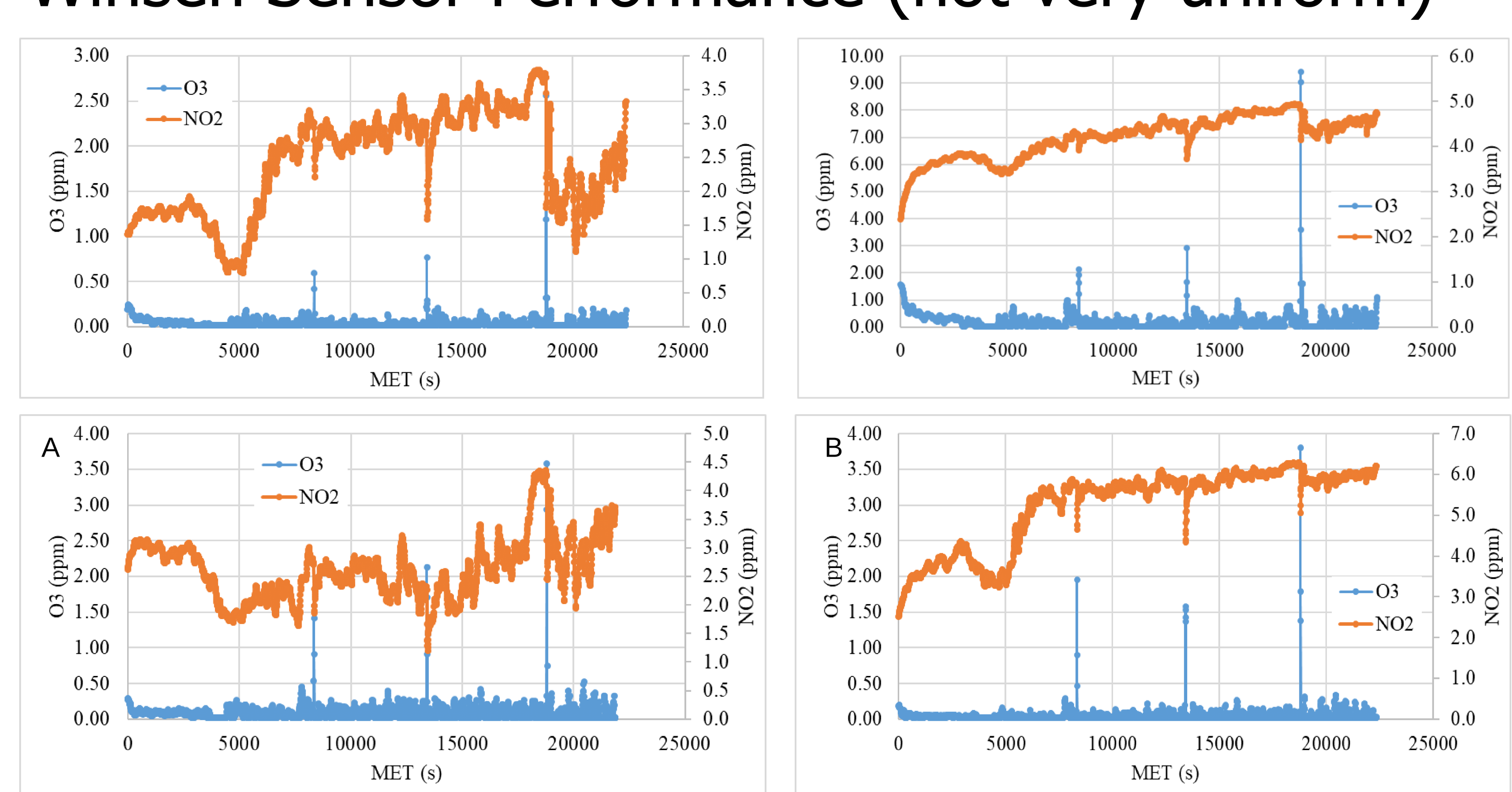

Figure 5. Sample data from four of the five test boards (raw data). All boards were collocated within one meter of each other and placed next to a Utah Division of Air Quality air monitoring station. Note the difference in scales and detailed shapes. Most of the general features are visible between all units, but the repeatability is subpar at best.

Individual tests near idling vehicles and close to highways shows the expected results but proper scaling will require careful calibration. This will make it more difficult for average users to obtain optimal performance.

Calibration

Initial calibration runs have been disappointing at best. Winsen's accuracy claims in their datasheet are simply wrong. Initial tests found:

- Temperature sensor was reading about 7 °C low.
- %RH was reading about 20%-points too high.
- The VOC sensor never responded to any alcohols, but the "formaldehyde" sensor responded to any alcohol and human breath.
- Both the CO2 and NO2 sensors responded to breathing.
- The O3 sensor had reasonable responses to an electric discharge.
- All the sensors detected auto exhaust in a parking garage.

All of these flaws appear to be easy to fix in the code.

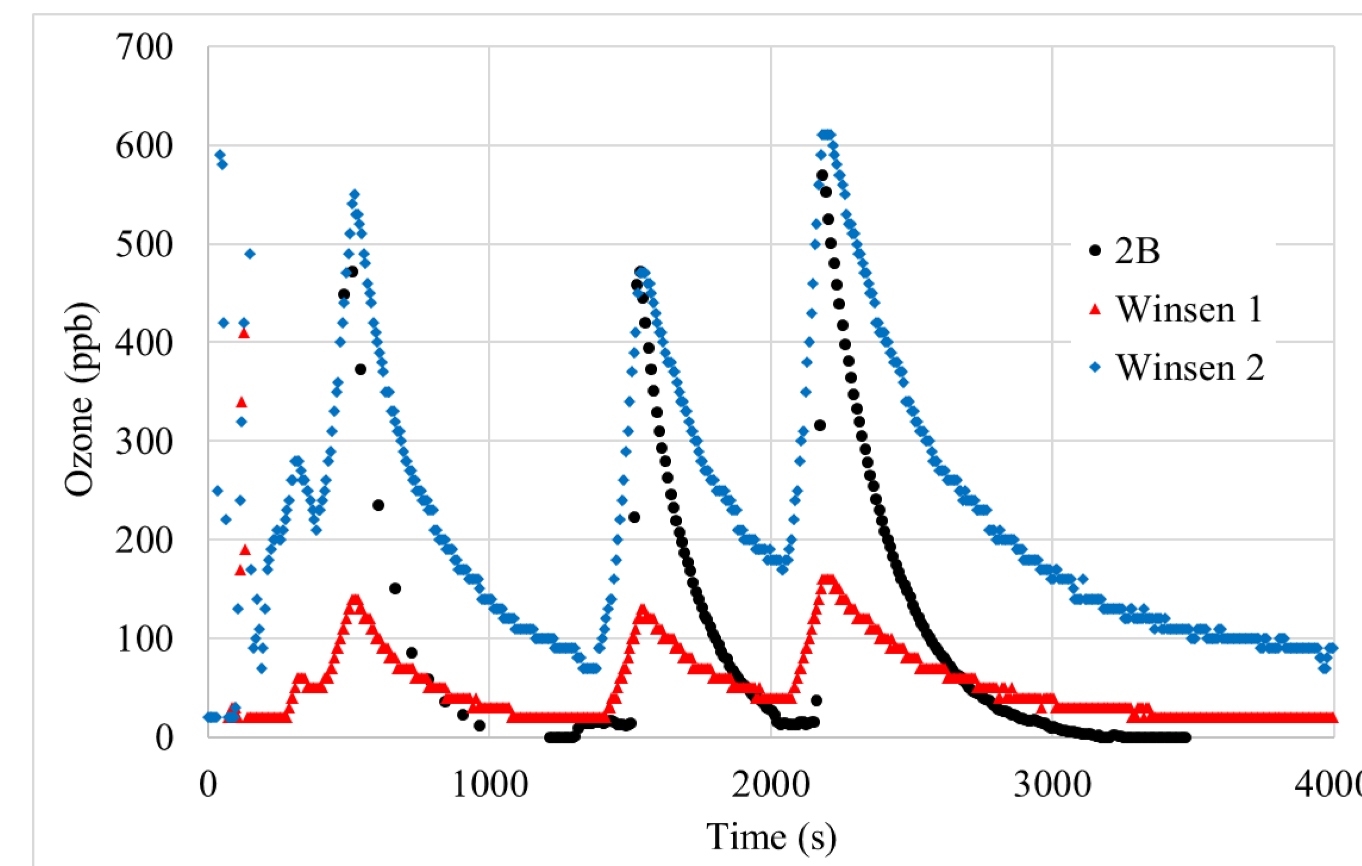

Figure 6. Board to board variance is large. Both Winsen sensors failed to reach zero. Their response time is slow as well. Output will need calibration but appears to be tracking together.

Initial Applications

We have partnered with Northrop Grumman in a high school outreach project to measure vehicle exhaust while idling at the school drop off. Those measurements will begin in early April. NG has purchased 4 miniMSAs for this project.

We will also partner with NG to make preliminary measurements of rocket exhaust plumes during the next rocket motor test firing.

We will fly several payloads in the next few months carrying an AtmoSniffer and/or an ozonesonde. These will also carry a miniMSA for comparison.

In late May 2021 we will fly a miniMSA through woodsmoke at a controlled burn at a local landfill.

Conclusions

Some of the gas sensors have strong cross-species sensitivity which will reduce the usefulness of the miniMSA, but most of the problems can be calibrated out. There appears to be a large variance between sensor sets. Initial tests support this being a useful, yet inexpensive, way to make rapid air quality measurements under small drones, balloons, or just sitting on a table.

Full calibration and testing will be completed by August 2021.

Contact us if you would like to be an alpha tester.

Acknowledgements

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