# The Umbrella Sensor Package


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LOYOLA UNIVERSITY CHICAGO

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The Morton Arboretum


## Introduction

### Problem Statement:

- The fundamental goal of this project is to aid in the arboreal research taking place at the Morton Arboretum. Although the Arboretum currently has sensors that can be placed on the lower trunk and ground to monitor tree health and ambient environmental conditions, the Arboretum has no sensor package that can be placed in the tree canopy.
- A comprehensive and robust sensor package is needed that can measure environmental conditions and record data within the tree canopy throughout an entire growing season (about 6 months). To accurately capture the environmental conditions within the tree canopy, the sensor package must measure sunlight, temperature, and humidity.
- In addition, the Arboretum is adjacent to a major highway. Consequently, the Arboretum likely experiences high concentrations of air pollutants, especially during high-traffic times. To quantify the danger posed to visitors, wildlife, and plants at the Morton Arboretum, the sensor package will measure particulate matter, extremely small particles emitted by vehicles that cause reduced lung capacity after extended exposure.
- Altogether, the Morton Arboretum allocated $1500 to test and construct the prototype sensor package.

### Background:

The Arboretum has developed an innovative method for implementing and retrieving the sensor package from the tree canopy. A drone, the DJI Matrice 600 Pro UAV, will carry and attach the sensor package into the tree canopy and later retrieve the sensor package at the end of the deployment period (*Figure 1*). Student engineers at Northern Illinois University (NIU) have designed and constructed the deployment/retrieval system (DRS) for the drone and the universal sensor mount (USM) to hold in place the sensor package and attach it to the tree canopy (*Figure 1*). Consequently, the sensor package must fit within the size and weight restrictions of the USM and DRS devices:

- Size Constraint: *8 in x 3.75 in x 3.11 in* [1]
- Weight Constraint: *8.14 lbs* [2]

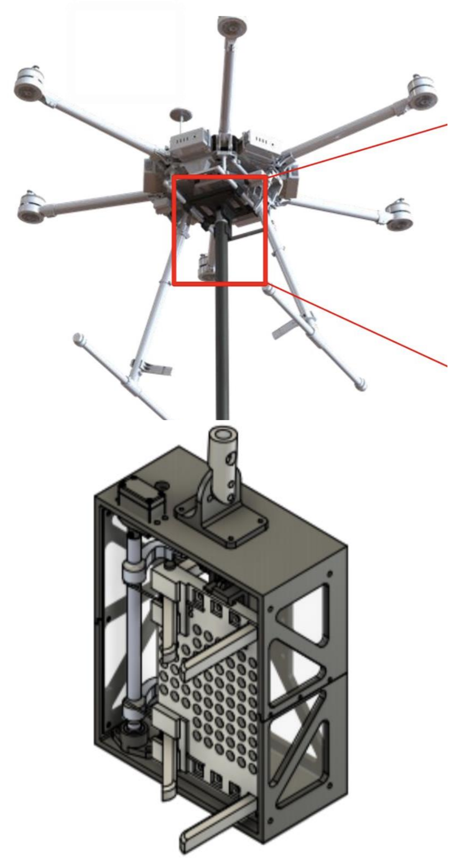
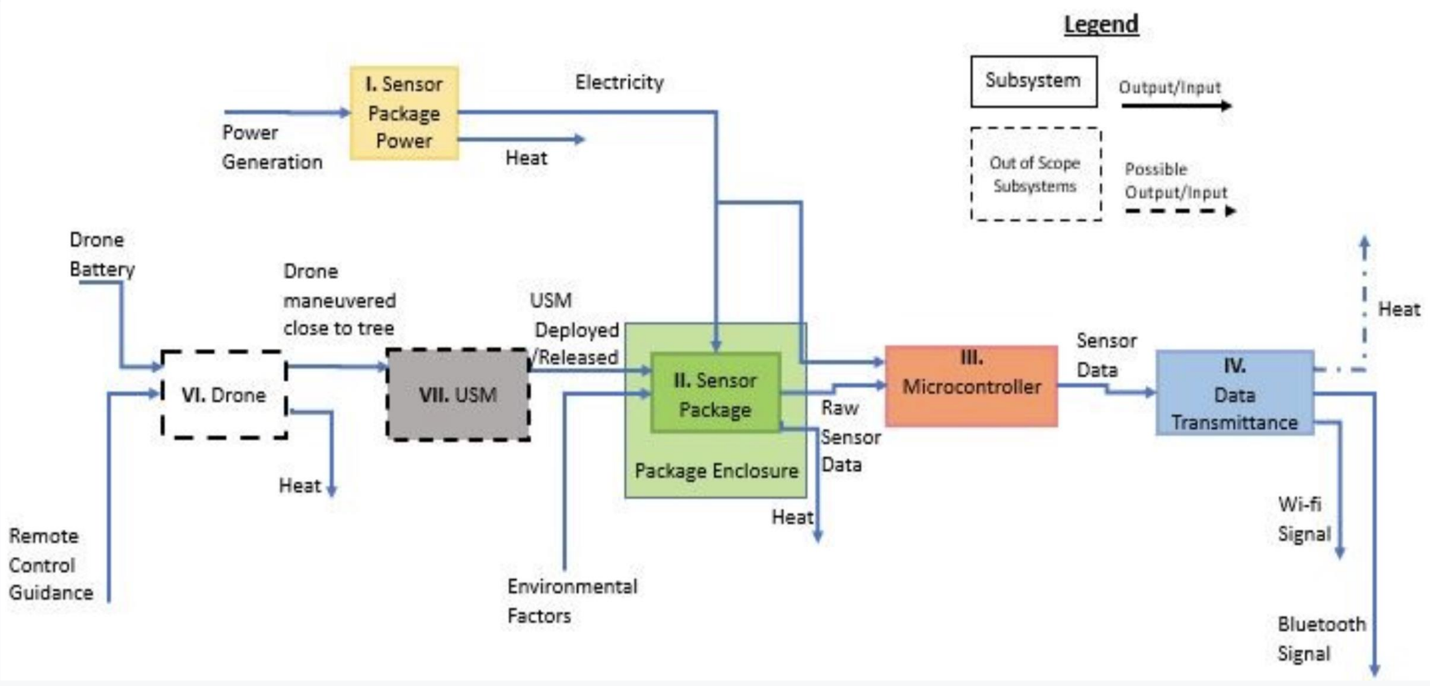


*Figure 1. Illustration of the drone and deployment/retrieval system.*

### System Diagram:




## Acknowledgements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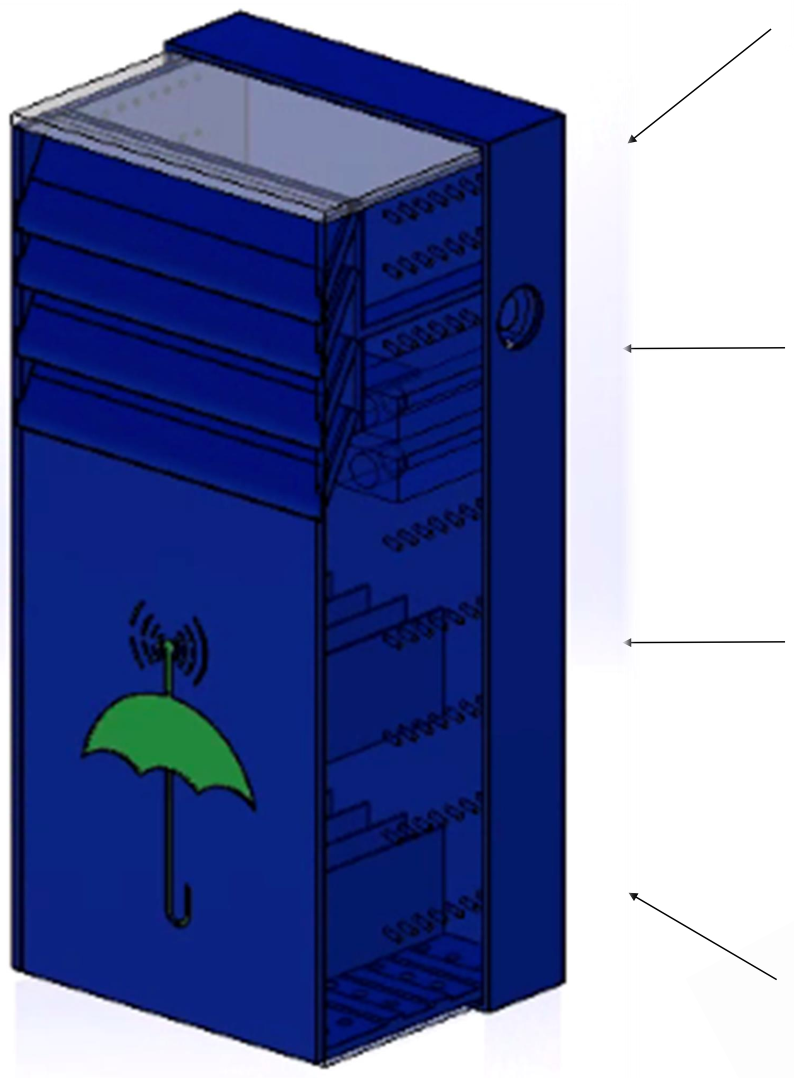

*Figure 2. Umbrella Sensor Package Enclosure 3D Model – Isometric View with Transparent Side Wall for Visibility*

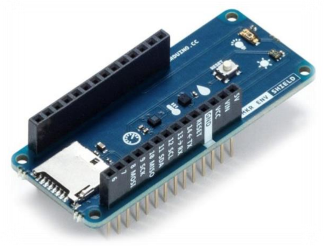

*Figure 3. Arduino MKR ENV Shield – Multi-sensor component chosen for temperature, humidity, and sunlight data measurement capabilities*

*Figure 4. Arduino MKR WIFI 1010 – Microcontroller component chosen for low-power and Bluetooth capabilities*

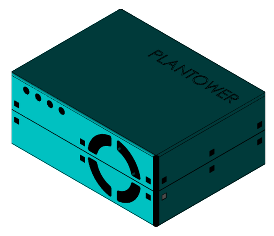


*Figure 5. PMS5003 – Individual sensor component chosen for particulate matter (2.5, 5.0, and 10.0 µm particles)*

*Figure 6. 3.7V 10000 mAh Li-Ion Battery – Individual Lithium-Ion battery pack chosen for high energy density; the package utilizes eight of these*

## Methods

### Sensor(s) Selection:

Three potential designs were compiled that fulfill the Arboretum's sensing requests: a high-cost Combined Design, a mid-cost Adafruit Design, and a low-cost Arduino Design. Although more accurate and comprehensive in sensing capabilities, the high-cost Combined Design was excluded early on by our sponsors due to its expensive nature. The mid-cost Adafruit Design and low-cost Arduino Design were pursued for further testing. Components for these two designs were purchased, assembled, and tested by the design team. Overall, due to ease of use and simplicity of operation, the low-cost Arduino Design was chosen for the prototype sensor package. Moving forward, the Arduino Design was tested and coded to increase power efficiency and ease of use.

### Battery Selection:

An appropriate battery system was chosen for the sensor package. First, the power requirements of the Arduino Design were determined. The power requirements vary substantially depending on how often measurements are taken.

### Enclosure Design Process:

Several iterations for a weatherproof enclosure were designed on SolidWorks 3D-design software and then 3D-printed with ABS plastic. Next, these designs were tested in a standard shower to gauge their ability to prevent rainwater from entering the enclosure at different deployment orientations. Overall, one design and orientation shown superior at weatherproofing: thickness of 0.1-inch thickness, straight edge cowls incorporated at a 60° angle, airflow holes with a diameter of 1/8 inch and angled at 45°, and deployment orientation between a 90° upright position and a maximum of 45° of additional rotation. Research indicated that the material of the final enclosure design should be acrylic to provide the rigid, durable, and water-resistant structure needed. The acrylic enclosure was assembled by laser-cutting acrylic panels and plastic welding. The lid of the enclosure is located on the back and consists of sheet metal aluminum. Steel bolts pass from the USM, through the sheet-metal lid, and into the acrylic enclosure to provide a secure attachment.

## Results

For our design to work, the sensor package must not only measure temperature, humidity, sunlight, and particulate matter, but accurately depict its surrounding environment. By simulating the integrated environmental sensor package over a designated amount of time, the accuracy of the data measurements can be signified. The following figures, Figures 7-10, respectively, illustrate measurements taken for ambient temperature, ambient humidity, ambient luminance, and ambient particulate matter during an ~30 minute period. Resultantly, for each data type measured, the accuracy for each is affirmed.

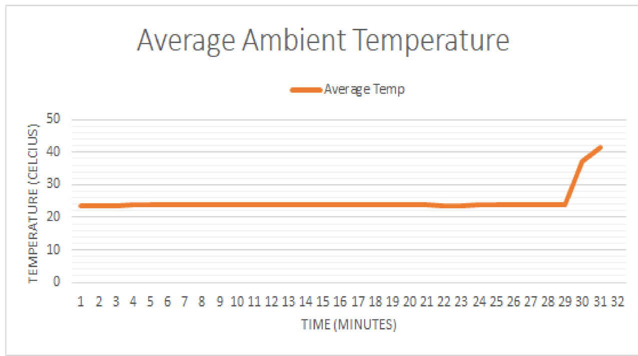


*Figure 7. Ambient temperature measurements from the Arduino MKR ENV Shield sensor*

Figure 7 measures the ambient air temperature with exposure to a hairdryer at the end of the time period.

Figure 8 measures the average ambient relative humidity of the environment with exposure to a hairdryer at the end of the time period, which raises the air temperature, increasing the amount of water vapor that can be held in the air. The increase in temperature and air storage results in lower relative humidity.

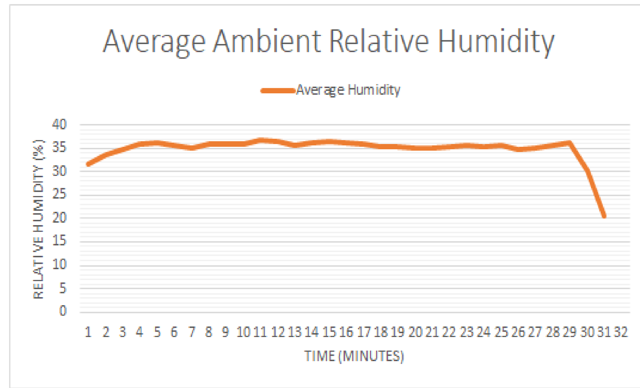


*Figure 8. Ambient relative humidity measurements from the Arduino MKR ENV Shield sensor*

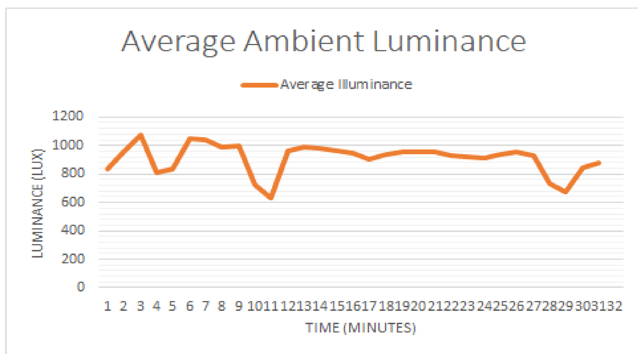


*Figure 9. Ambient luminance measurements from the Arduino MKR ENV Shield sensor*

Figure 9 measures the average ambient light of the environmental sensor package. The device was placed on an East-facing windowsill. Fluctuations in the measured light are attributed to the amount of visibility the sensor has to the environment. The drops in measured lux can be due to cloud coverage, changing the position of the sun, and blockages in the device's visibility.

Figure 10 measures the ambient particulate matter detection of smoke. A piece of paper was lit and as the smoke diffused through the air, the PM sensor sampled the air. As the concentration of smoke increased, so did the particulate matter in the air, which can be seen peaking around 22 seconds of exposure. The three size of particles measured are 1.0, 2.5, and 10.0 µm via laser diffraction analysis.

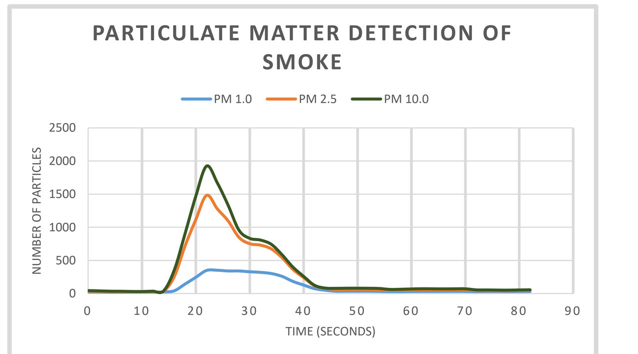


*Figure 10. Ambient particulate matter measurements from the PMS5003 sensor*

## Discussion

The final design, named the Umbrella Sensor Package, consists of components from the company Arduino. Capable of all the sensing needs required, the Umbrella Sensor Package records data on a microSD card. Using a Bluetooth/Wi-Fi module, the design also periodically transmits a signal to researchers on the ground nearby signifying that all systems are running normally while also providing real-time data checks. The Umbrella Sensor Package has been coded to optimize power efficiency and ease-of-use. Seven 3.7V 10,000mAh lithium-ion polymer batteries wired in parallel provide power for the design. At minimum recommended sensing frequencies, the Umbrella Sensor Package has enough power to last 6 months, the length of an entire growing season. Finally, a weatherproof, tamper-resistant enclosure has been designed, consisting of acrylic and aluminum sheet metal.

## References


*[1] C. Borchetta, "DS-USM", 2020, Morton Arboretum.*

*[2] P. Brudi, J. Byrnes, and Paul Wohler. (2020). Drone-Enabled Sensing and Monitoring of Tree Canopies [PowerPoint slides]. Available: Morton Arboretum.*