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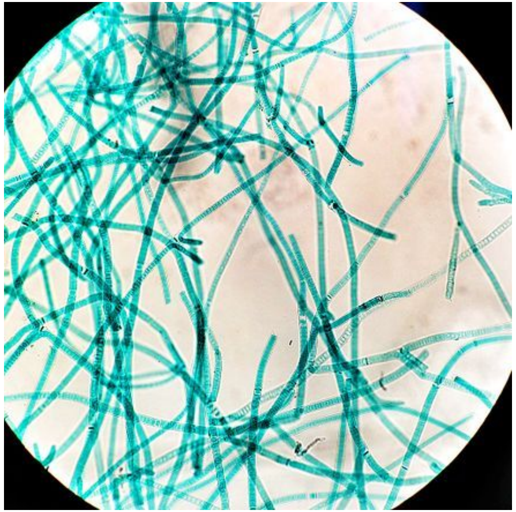
Kennesaw State University

Low Cost Remote Algae Detection Utilizing Embedded Hardware, Custom Sensors, and Additive Manufacturing

Charles Wade
Department of Electrical Engineering and Computer Science
The University of Toledo
Toledo, Ohio

What are Harmful Algae Blooms(HABS)?

General Overview of Algae



Algae is a broad definition:

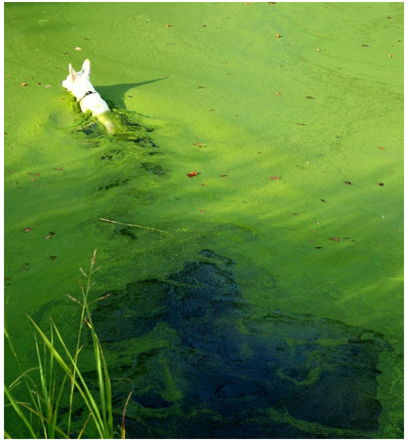
- Algae includes organisms like seaweed and phytoplankton

Blue-Green Algae (Cyanobacteria)

- Consume **nitrogen** and **phosphorus**
- Perform photosynthesis

Why Algae is a Problem

- Pulls oxygen out of the water creating dead zones of life
- Releases toxins that sicken or kill living creatures
- **Contaminates clean water supplies**



$65 million

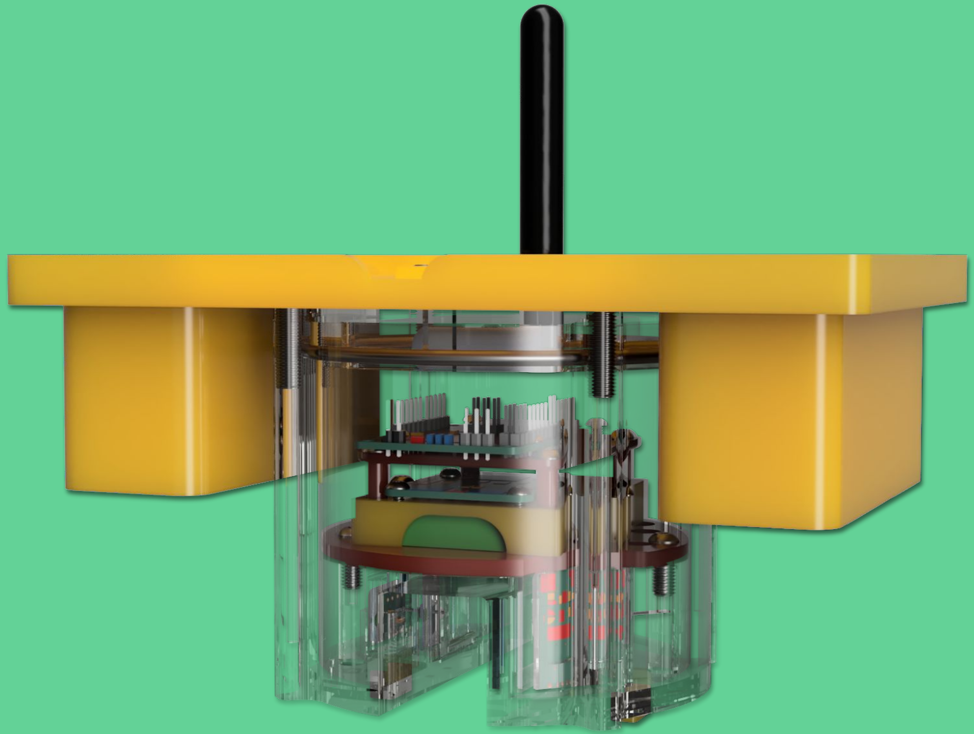
Estimated economic impact of the 2014 algae bloom in Toledo, Ohio, according to National Ocean and Atmospheric Administration(NOAA)

Current Methods of Tracking Algae

- **Phosphorus sensors** are the main way algae is detected

- Satellite imagery has started to be used to track algae

- Most tracking and **sampling is done via boat**

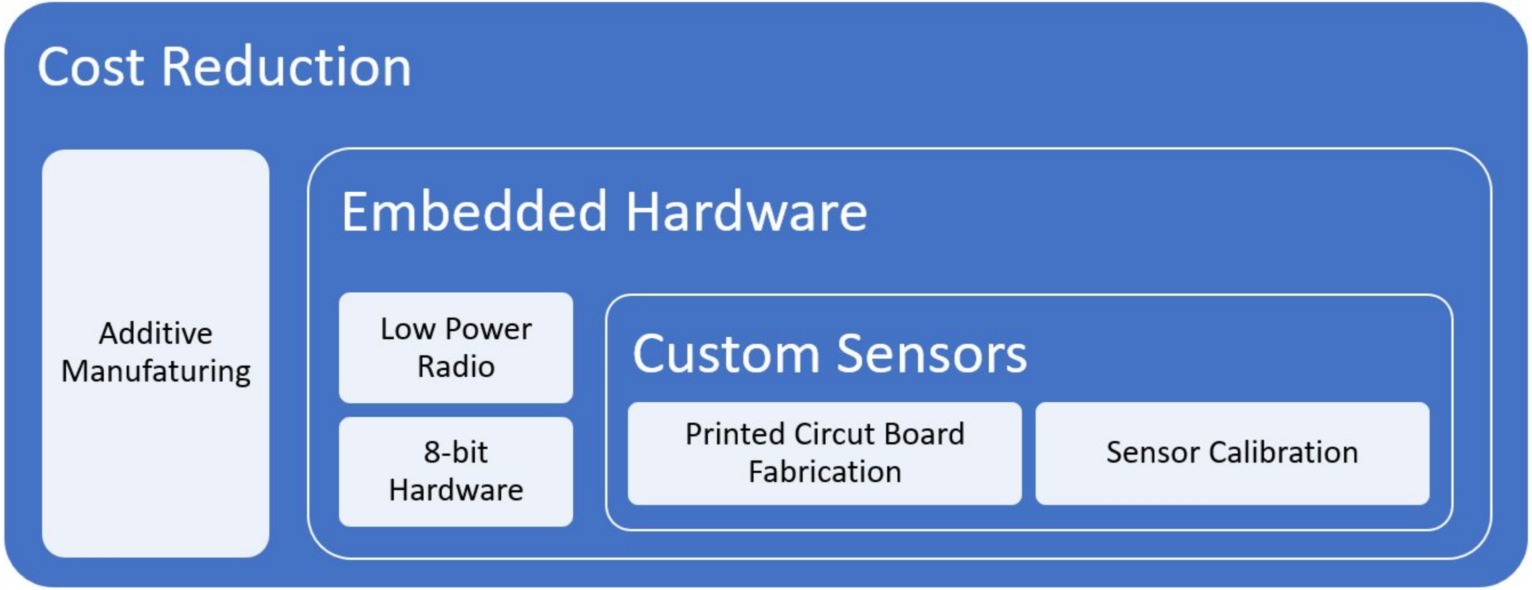


READ

Remote **E**lectronic **A**lgae **D**etector

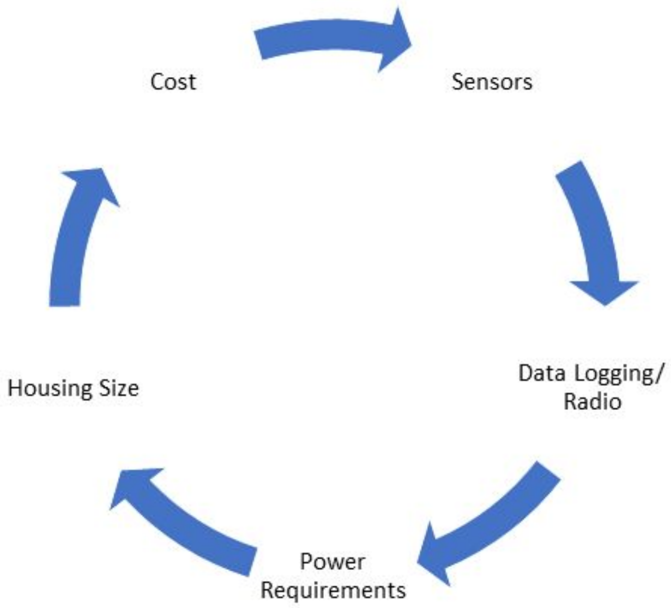
Goals

- **Reduce the cost** of remote algae monitoring.
- **Provide easier access of HAB data** to scientists and health officials.
- **Automate water sampling** efforts



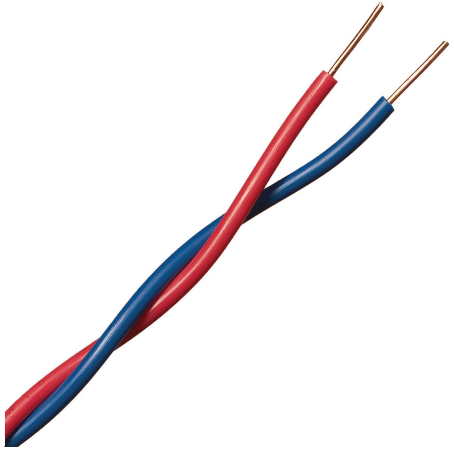
Embedded Hardware

Minimizing costs by reducing the size and complexity of computer systems/ sensors.



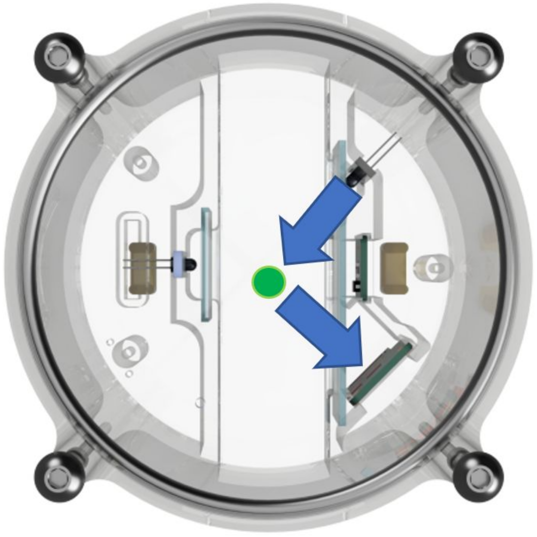
Custom Sensors

- **Reduce cost** and minimize space consumption
- 4 sensors were used: *conductivity, color, turbidity, and chlorophyll*
- **Form a redundant system** in case of sensor failure

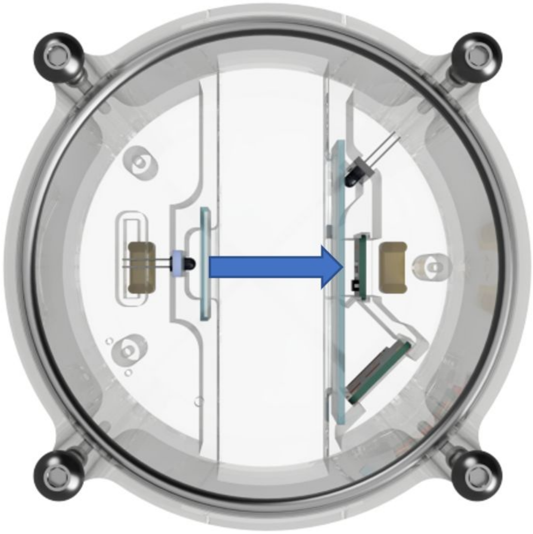


Chlorophyll

- Uses **fluorometry** to detect algae.
- The LED emits blue light at 470 nm to irritate the chlorophyll in the algae.
- The photodiode reads the now irritated chlorophyll through a red filter to block out excitation light.



Color and Turbidity



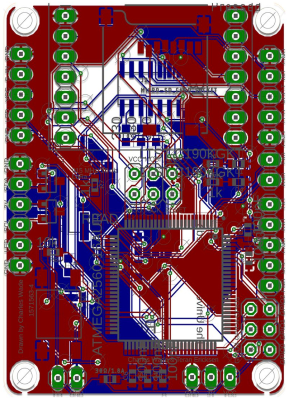
- The white LED **emits light through the water to the** TCS34725 **RGB Sensor** to collect the color and turbidity reading

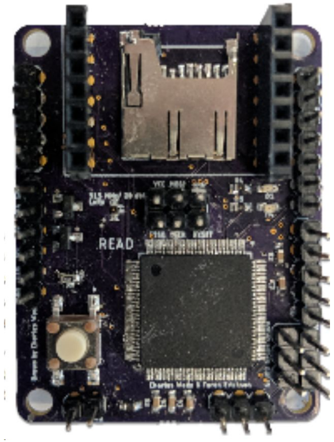
Command and Control

A **custom control board was designed** to be embedded into the detector.

Specifications:

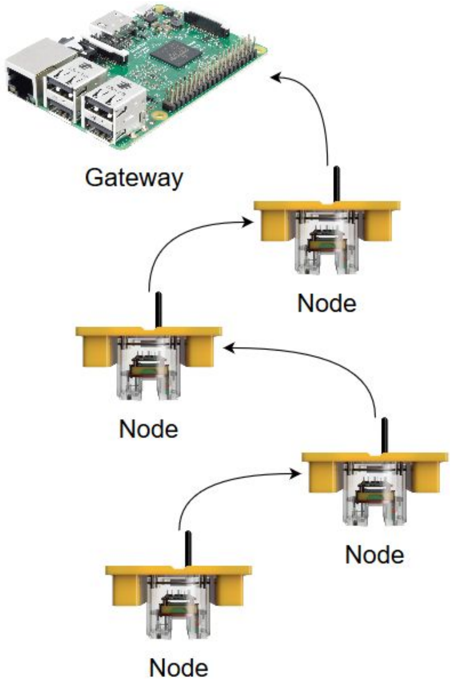
- ATmega2560
- microSD Card Support
- Real Time Clock
- 3.3V ⇔ 5V Logic Converters
- Radio Interface
- 50 GPIO Pins





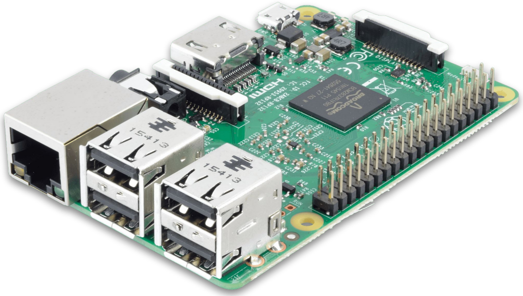
Radio Communication

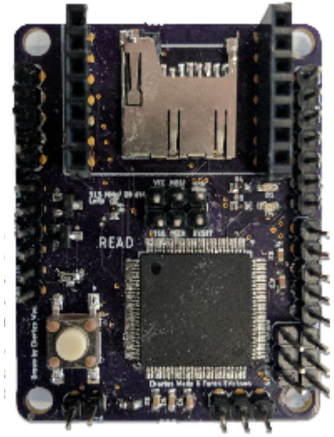
- The system utilized the LoRa(**L**ong **R**ange) radio protocol.
- To reduce memory requirements, only the LoRa physical layer is used, as opposed to not the entire LoRaWAN stack.
- Basic **Mesh Networking** Capabilities

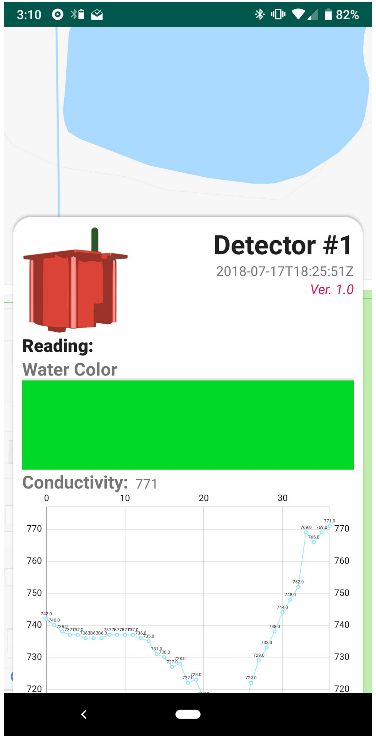


Data Logging

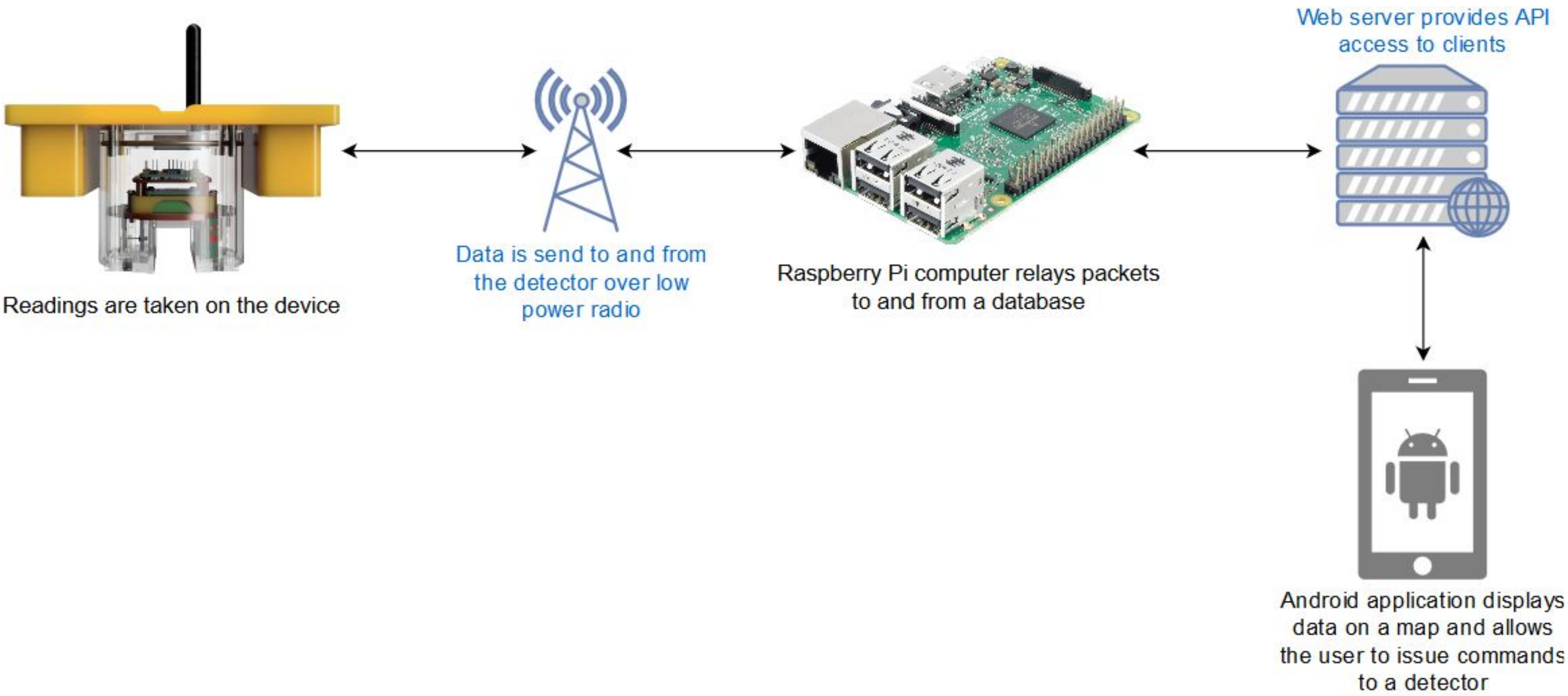
- Raw sensor data is **relayed over radio to a gateway** module.
- This data is then stored in a **SQLite database**.
- A **web server provides API access** to an **Android application** that displays detectors on a map.





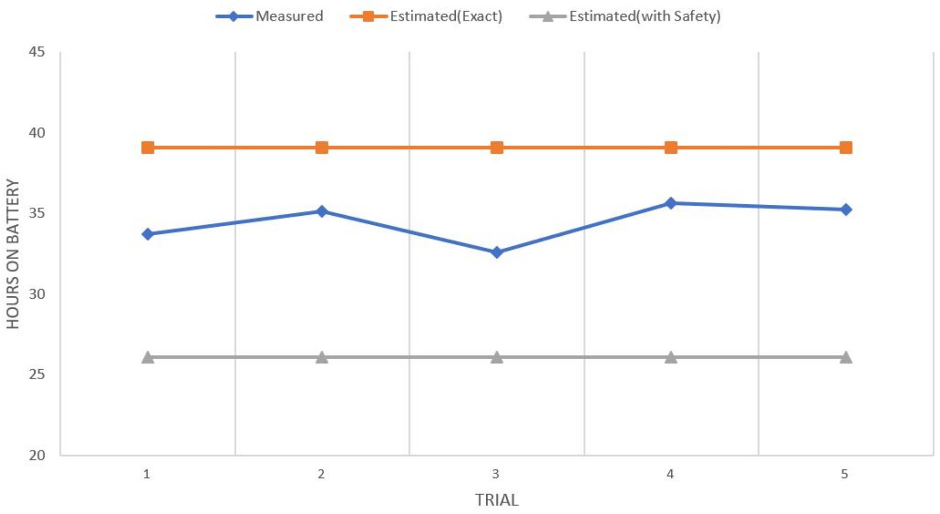


Architecture Overview

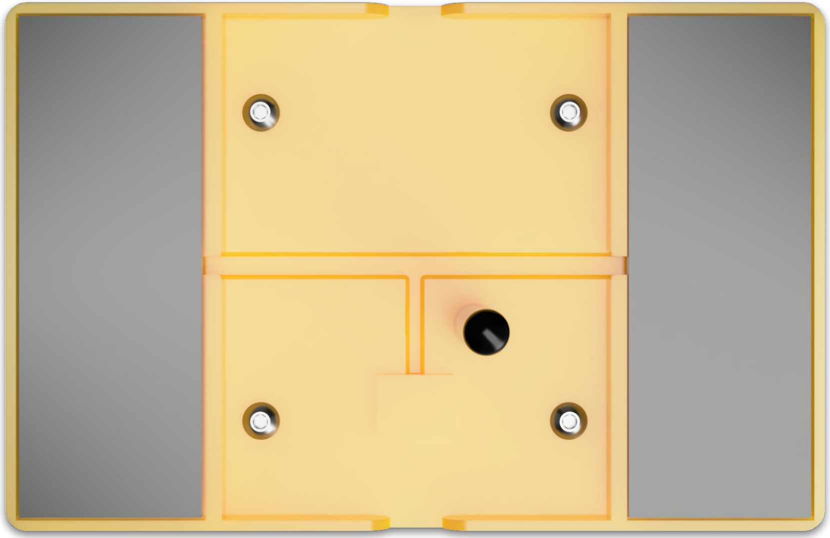


Power Requirements

- Two half-watt solar panels and a rechargeable battery provide enough energy continuous operation.

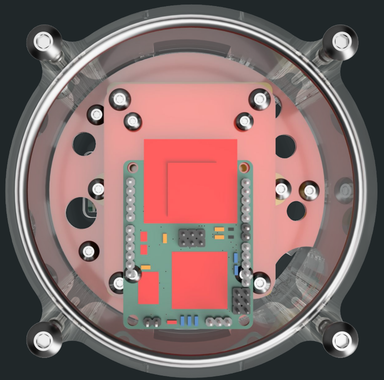


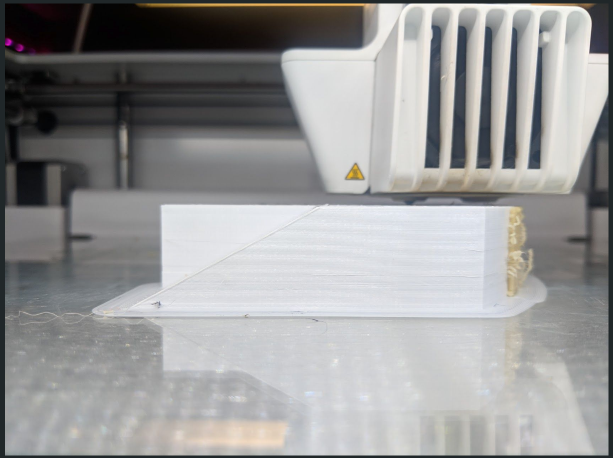
Battery trial results: Measured time on battery verses ideal battery life with and without a safety factor of 1.5.



Housing

Additive Manufacturing provides both flexibility and customizability to enable a small and robust housing for the electronics.





Hobby-Level 3D Printing for Aquatic Environments

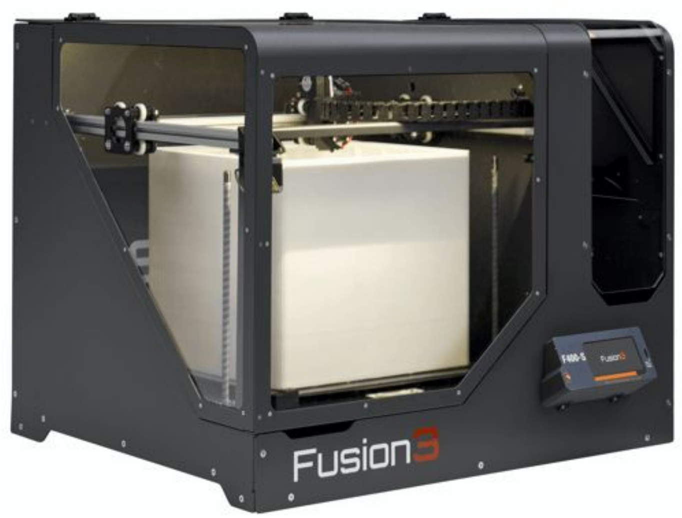
- Different 3D printed housings were tested in water.
- **FDM** and **SLA** printing were both tested.
- The current design utilizes both FDM and SLA techniques.

Design Evolution

3D Printing Test Setup

FDM: Fused Deposition Modeling

Materials: PLA, ABS, PETG



SLA: Stereolithography

Materials: FormLabs Standard Resin

FDM Results

- FDM printing worked best when **printed with >90% infill** using **PETG** or **ABS** filaments, however **was still susceptible to leaks after spending more than 3 days in water**.
- Leaks were caused by water entering the imperfections left behind from layer adhesion.

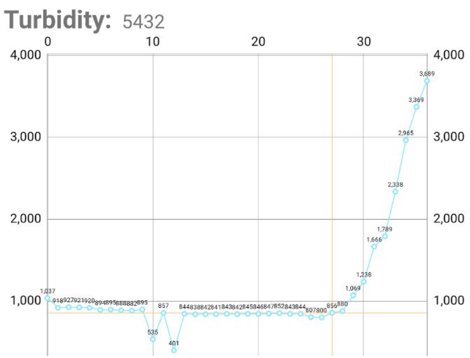
SLA Results

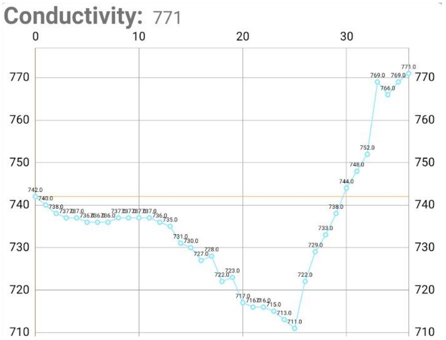
- SLA printing **was *not* susceptible to leakage through layers**.
- Test prints were capable of **withstanding upto three weeks fully submerged** before leaks presented.
- Stronger UV cured materials might yield greater watertightness.

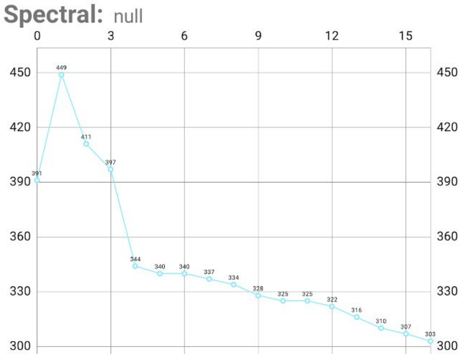
Field Testing

Three-week deployment at The University of Toledo **Lake Erie Center**

Sensor Test Results



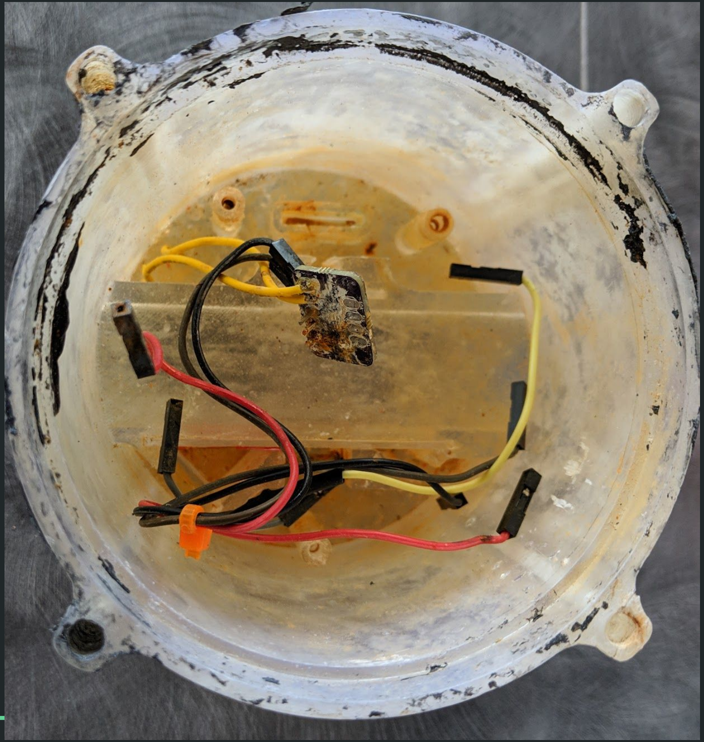




- Scaling of the graphs are in the raw sensor readings
- The spike in conductivity and turbidity graphs is caused by runoff from a storm

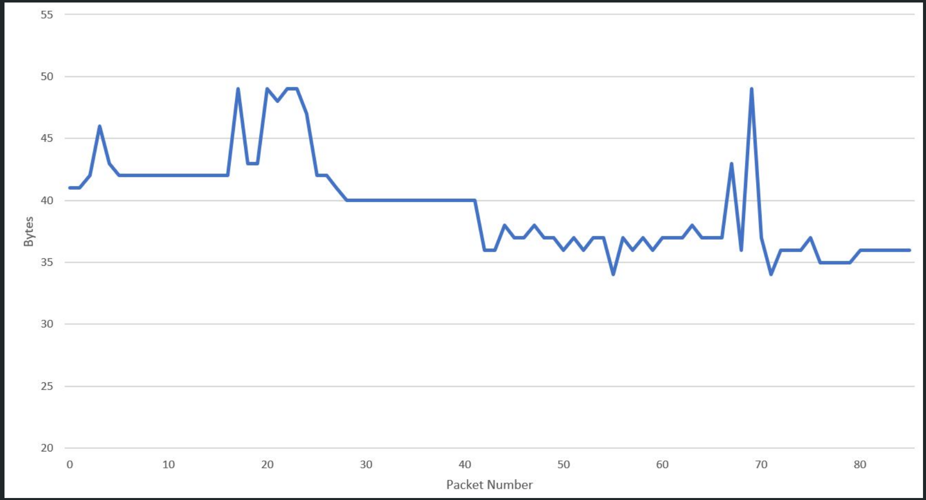
Housing Results

- SLA print deteriorated around the acrylic windows
- Caused a slow leak that eventually shorted the detector



Radio and Data Logging Results

- **All packets were received by the gateway** at expected intervals.
- Invalid sensor readings caused by the leaking housing were also correctly identified and flagged.
- The radio packet size never exceeded the maximum 255 bytes.



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Questions?