Turbidity Sensor Senior Design Project

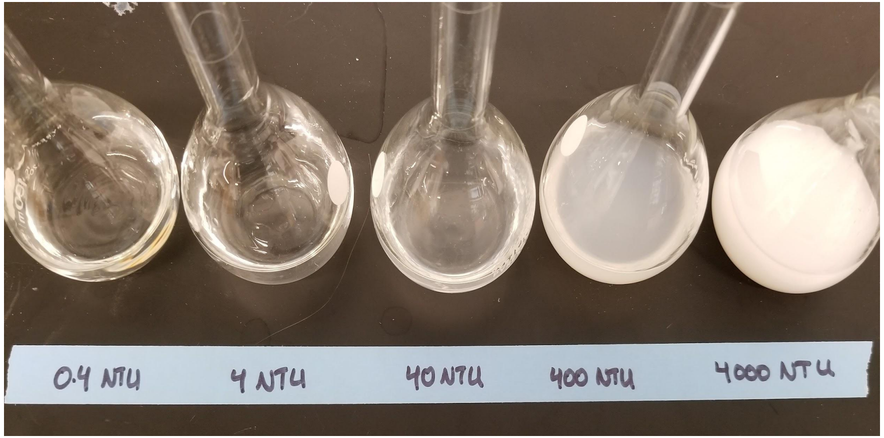
Team: Corbin Buechler, Amanda Hayden, Aaron Nightingale, Sean Rogers, Erik Sundberg, Jacob Wolf

Advisor: Joey Talghader

Clients: Andy Wickert, Anthony Aufdenkampe, Diana Karwan

What is Turbidity?

- Cloudiness or haziness of a fluid caused by small particles
- Generally not visible to naked eye
- Key test for determining water quality
- Quantifies water pollution in Minnesota



What is Turbidity?

- Common drinking water standards:
  - WHO Rating: ≤ 5 NTU (ideally ≤ 1 NTU)
  - European Rating: ≤ 4 NTU
  - US Rating: ≤ 1 NTU (ideally ≤ 0.3 NTU)
- Existing Sensors:

- Hach 2100Q Portable Turbidimeter
- $1215

- Davis Thermo Scientific AquaSensors DataStick AquaClear On-Line Turbidimeter
- $1970

Project Proposal

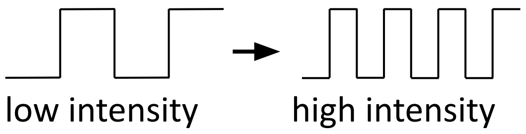
- Develop a functional, low-cost turbidity meter
- Uses light scattering to determine the turbidity
- Specifications:
  - Communicates with an open-source data logger
  - Arduino-based code
  - Integrate software libraries
    - ALog
    - Mayfly
  - Low power for prolonged deployment, up to 3 months
  - Must be waterproof, submersible up to 3 meters
  - Cost less than $100 to produce
- Field deployable by April

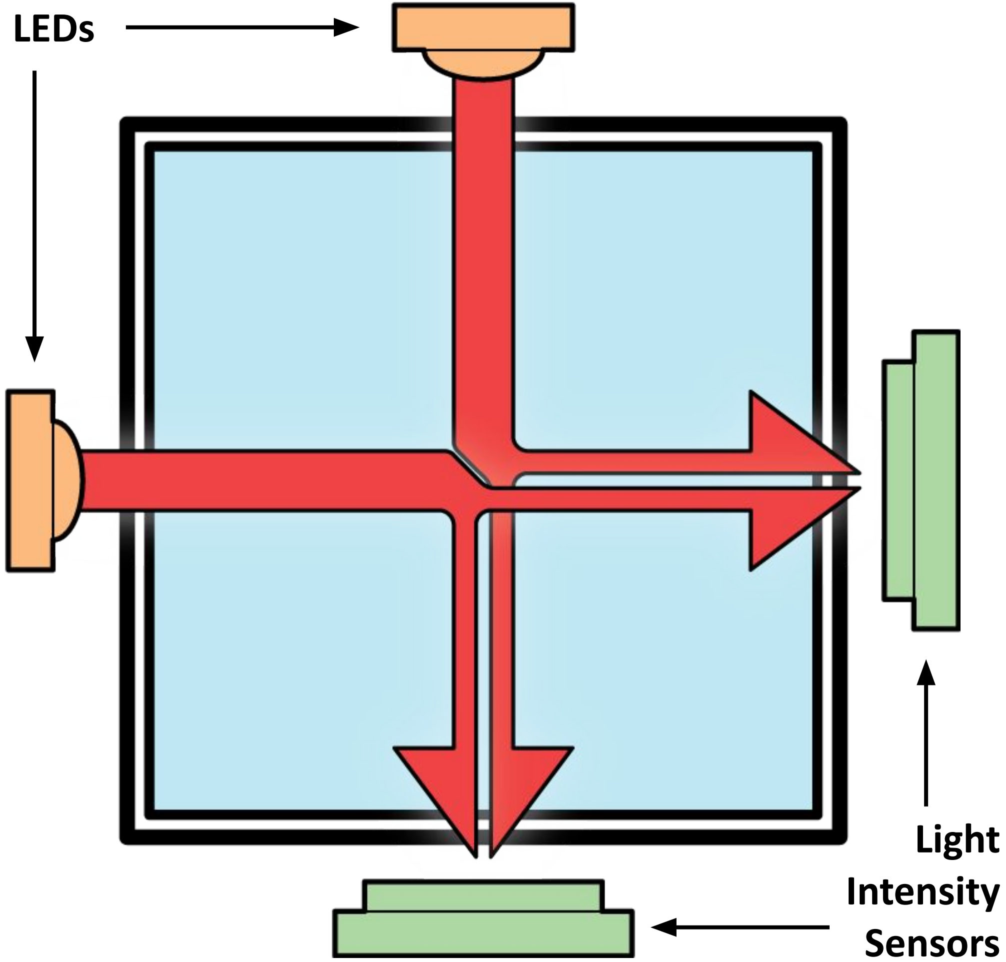
Team Organization

- **Amanda -** Team Lead, Housing, Waterproofing
- **Corbin** - Sensor Code, Circuit Design
- **Aaron** - Communications, Data Logger Interfacing
- **Erik** - Hardware Layout, Mounting, 3D modeling
- **Sean** - Housing, Cabling, Waterproofing
- **Jake** - Waterproofing, Optics/Hardware Integration

Measurement Process

- Sensors measure light transmission and 90-degree side scatter through a liquid sample
- Infrared LEDs are illuminated at a HIGH and a LOW intensity
- Light Sensors output a square wave signal proportional to light intensity received

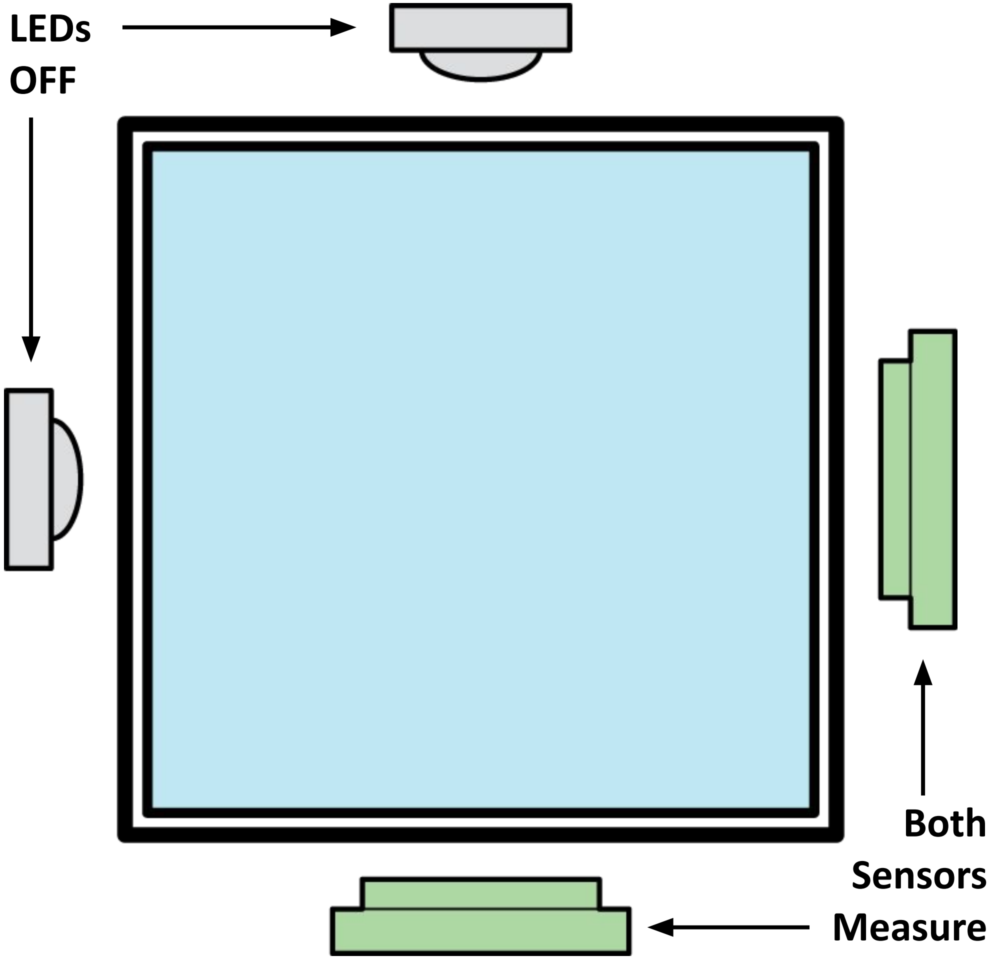




Measurement Process

Ambient Light Measurements

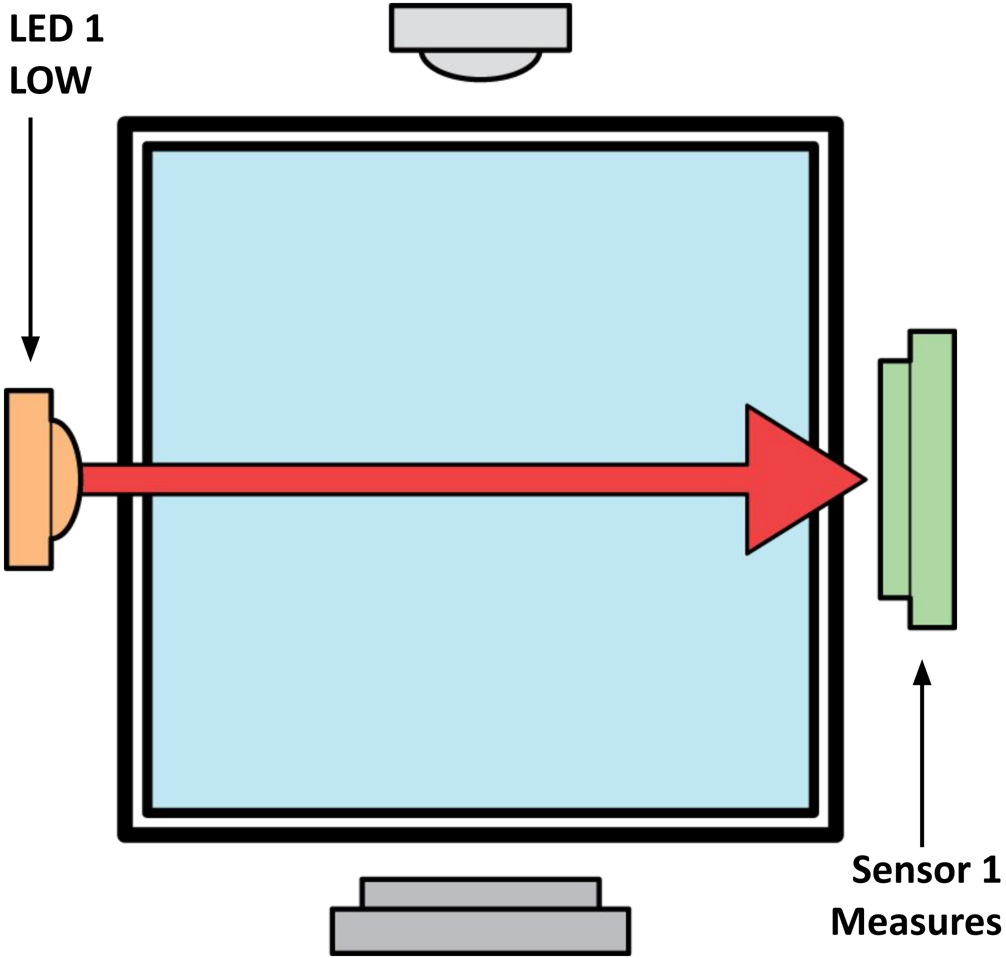
- Both LEDs are turned OFF
- Each sensor collects the amount of ambient light present to control for environmental factors like sunlight
- Serves as a baseline to normalize the following measurements



Measurement Process

LED 1 Transmission Measurement

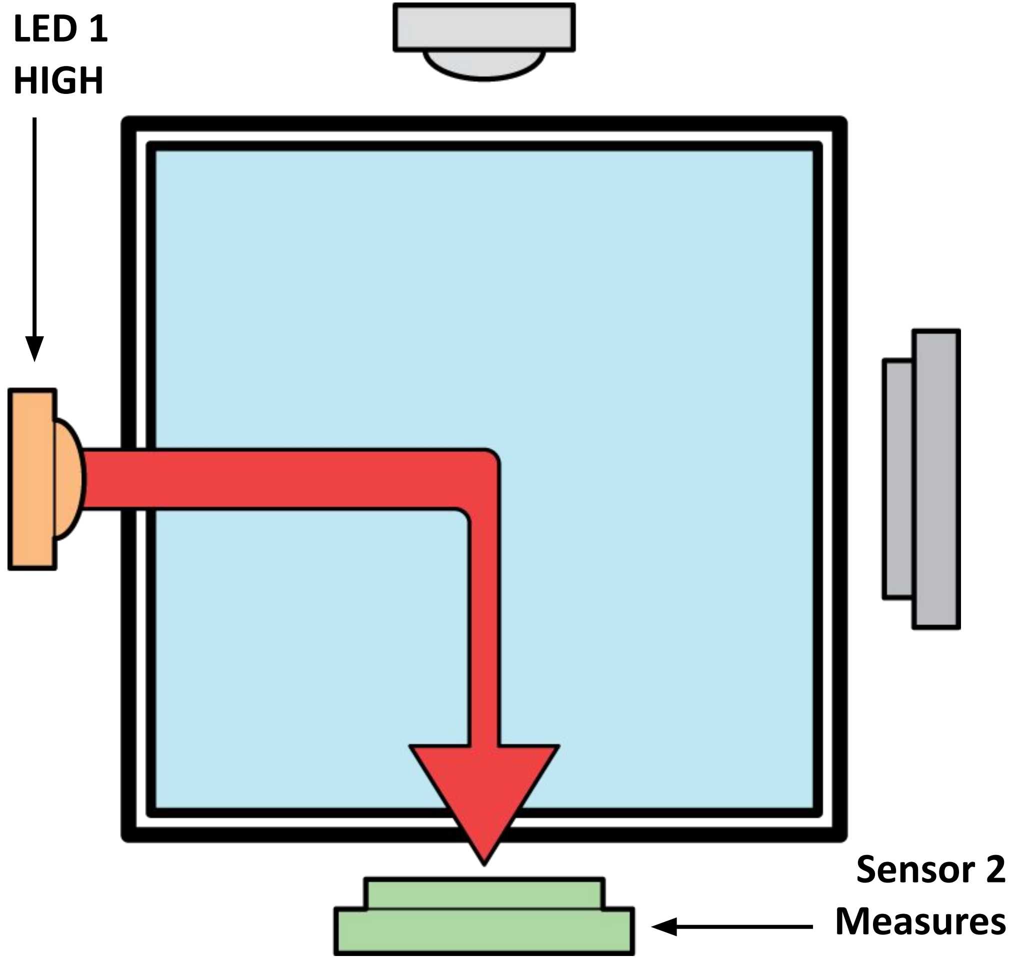
- LED 1 illuminated at LOW intensity
- Sensor 1 collects transmitted light



Measurement Process

LED 1 Side Scatter Measurement

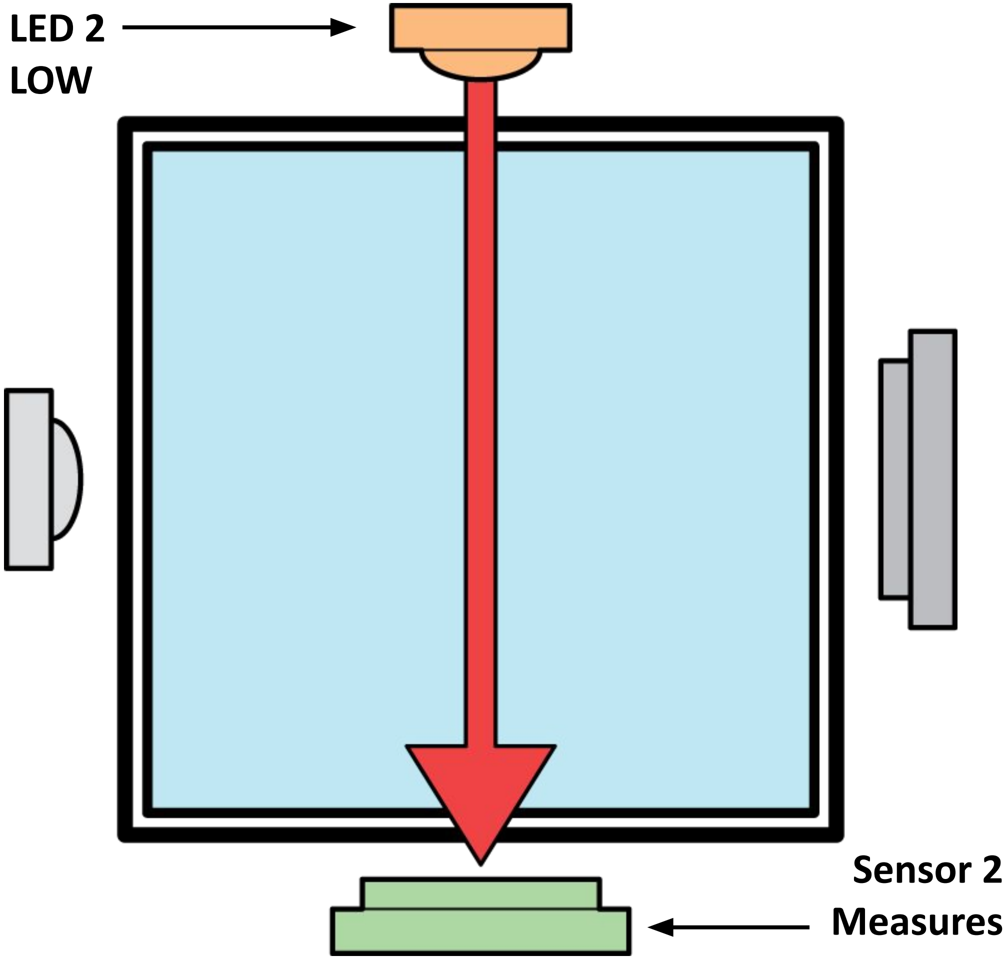
- LED 1 illuminated at HIGH intensity
- Sensor 2 collects scattered light



Measurement Process

LED 2 Transmission Measurement

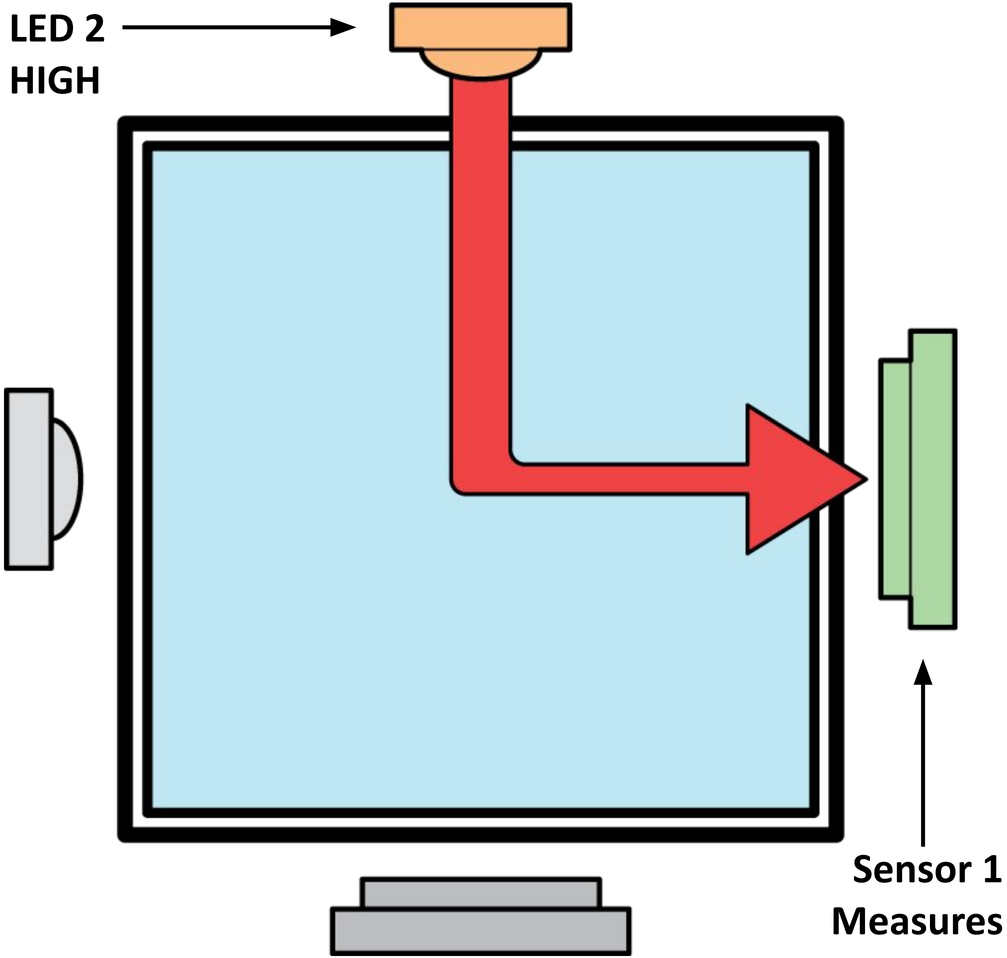
- LED 2 illuminated at LOW intensity
- Sensor 2 collects transmitted light



Measurement Process

LED 2 Side Scatter Measurement

- LED 2 illuminated at HIGH intensity
- Sensor 1 collects scattered light



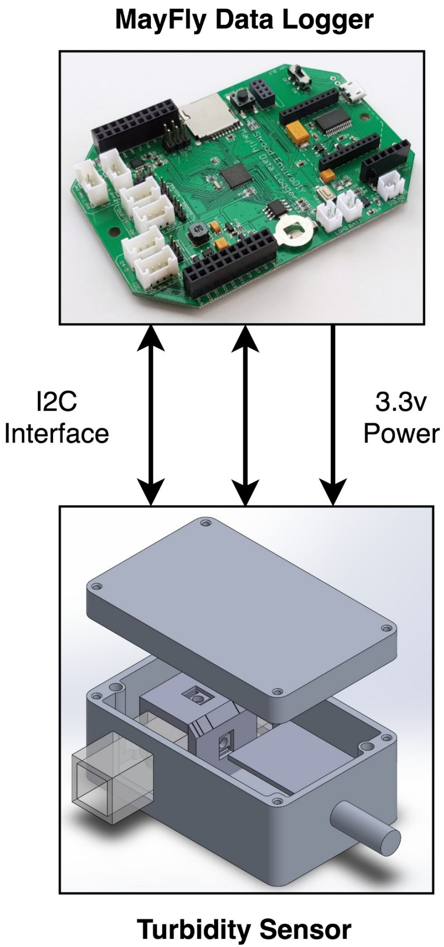
More on Measurement Process

- Measurement routine is repeated five times
- ATmega328P microcontroller collects frequency output by counting rising edges
- Microcontroller averages the five samples of the six measurements
- Measurements are held until the data logger requests them
- Conversion to NTU and long term storage is handled by the data logger

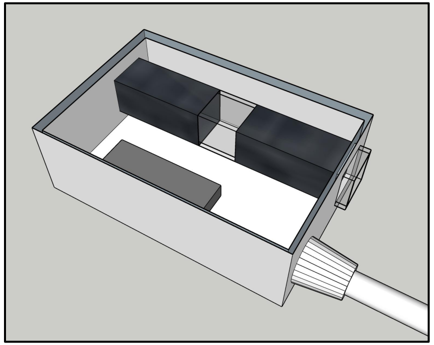
Communications

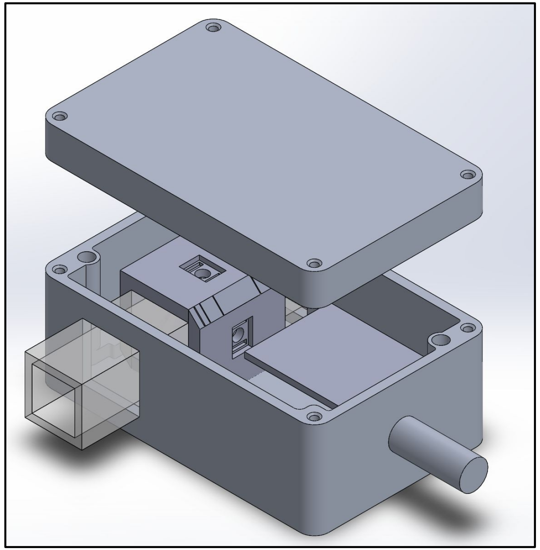
- **Goal:** A turbidity sensor that can communicate with the MayFly and ALog data loggers.

- **Communications Process**
  - Datalogger (master) requests data from sensor (slave) over I2C interface
  - Sensor sends previous readings
  - Data logger sends “UPDATE” command
  - Sensor takes new measurements (8 minute process)
  - Data logger waits ~10 minutes for next measurement
- **End Result?**
  - Turbidity Sensor Library (ALog & Mayfly compatible)



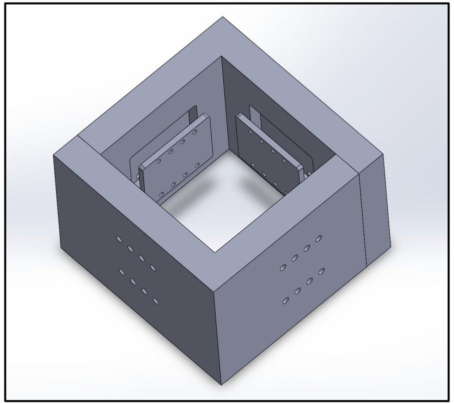
Hardware Integration / Layout

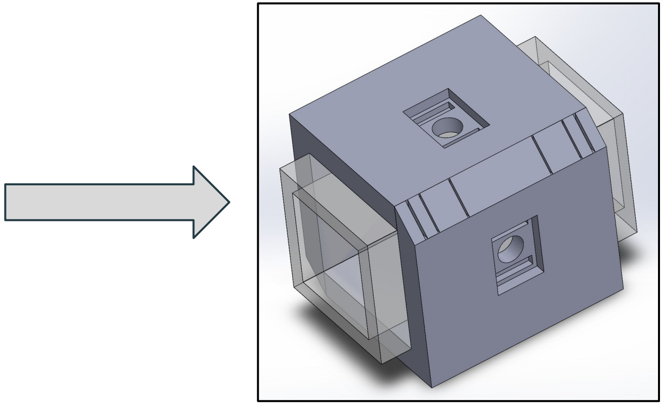


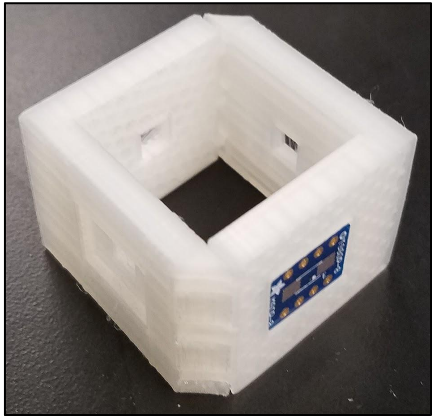


- Solidworks modeling software (right)
- Horizontal mounting of tube
  - Better waterflow
- Internal circuitry has exact dimensions for fitting
  - Enough for perfboard containing all necessary elements
- More space for mounting sensors around tube

Hardware Integration / Layout







Sensor & LED Mounting

- Small breakout board to solder IR sensor and LEDs
- 3D printed parts refined to mount on outside
- Two parts for easy assembly
- Angled sides for fitting in box
- Indents for wire ends and hole for sensors/LEDs
- Tolerancing

Housing, Cabling and Waterproofing

Ingress Protection (IP) Ratings

- Indicates level of dust and water intrusion protection
- International standard

First Digit: IP68

- **Indicates Dust and Particle Size Protection**
  - **0: not protected**
  - **1: >50mm**
  - **2: >12.5mm**
  - **3: >2.5mm**
  - **4: >1mm**
  - **5: Dust protected**
  - **6: Dust tight**

Second Digit: IP68

- **Indicates Water Protection**
  - **0: not protected**
  - **1: Dripping water**
  - **2: Dripping water when tilted at 15°**
  - **3: Spraying water**
  - **4: Splashing water**
  - **5: Water jets**
  - **6: Powerful water jets**
  - **7: Immersion up to 1 meter**
  - **8: Immersion beyond 1 meter**

Housing, Cabling and Waterproofing

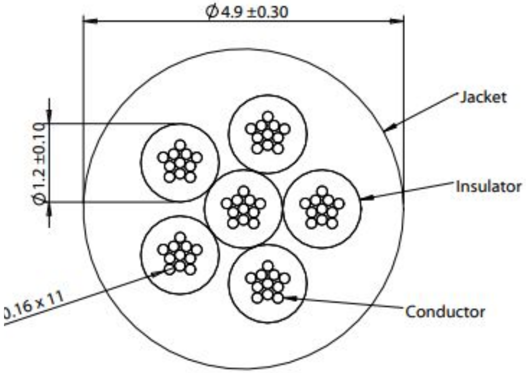
PolyCase AN-14P Enclosure

- Die cast aluminum box
- IP68 Rated
- Watertight gasket
- EMI/ RFI protection

Housing, Cabling and Waterproofing

Switchcraft Watertight Plugs

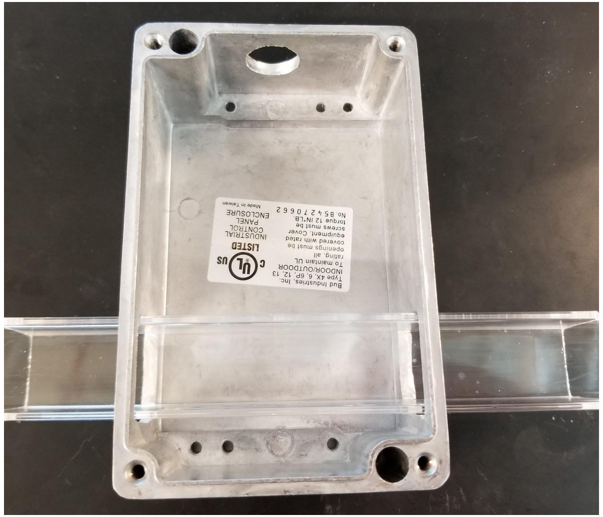
- Twisting Lock Mechanism
- Integrated rubber gaskets and strain relief



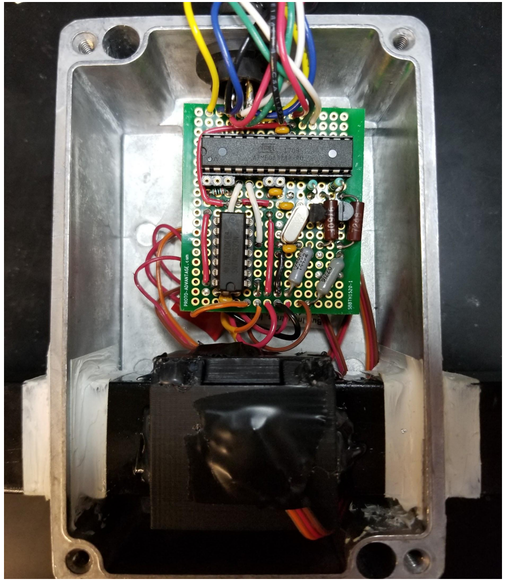
24 gauge 6-Strand

SRPVC Cable

Enclosure Construction



1. Completed tube and plug cutouts



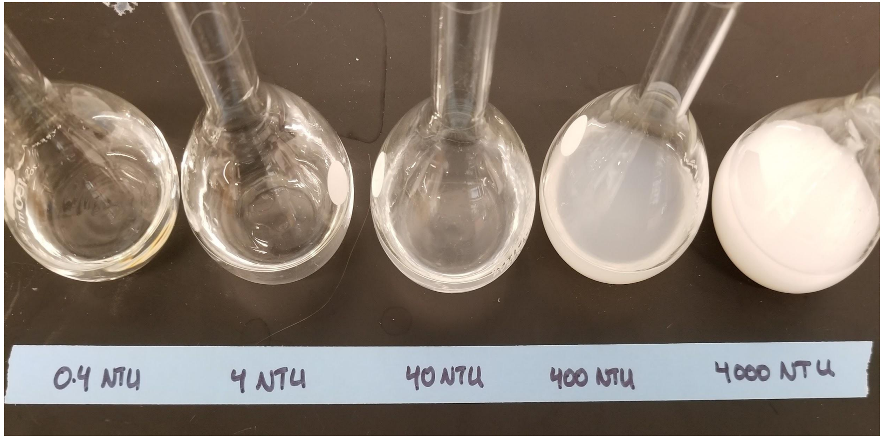
2. Assembled enclosure interior

Calibration

Serial dilutions to different turbidity values

- 4000 NTU
- 400 NTU
- 40 NTU
- 4 NTU
- 0.4 NTU

Five (5) sets of measurements at each NTU value

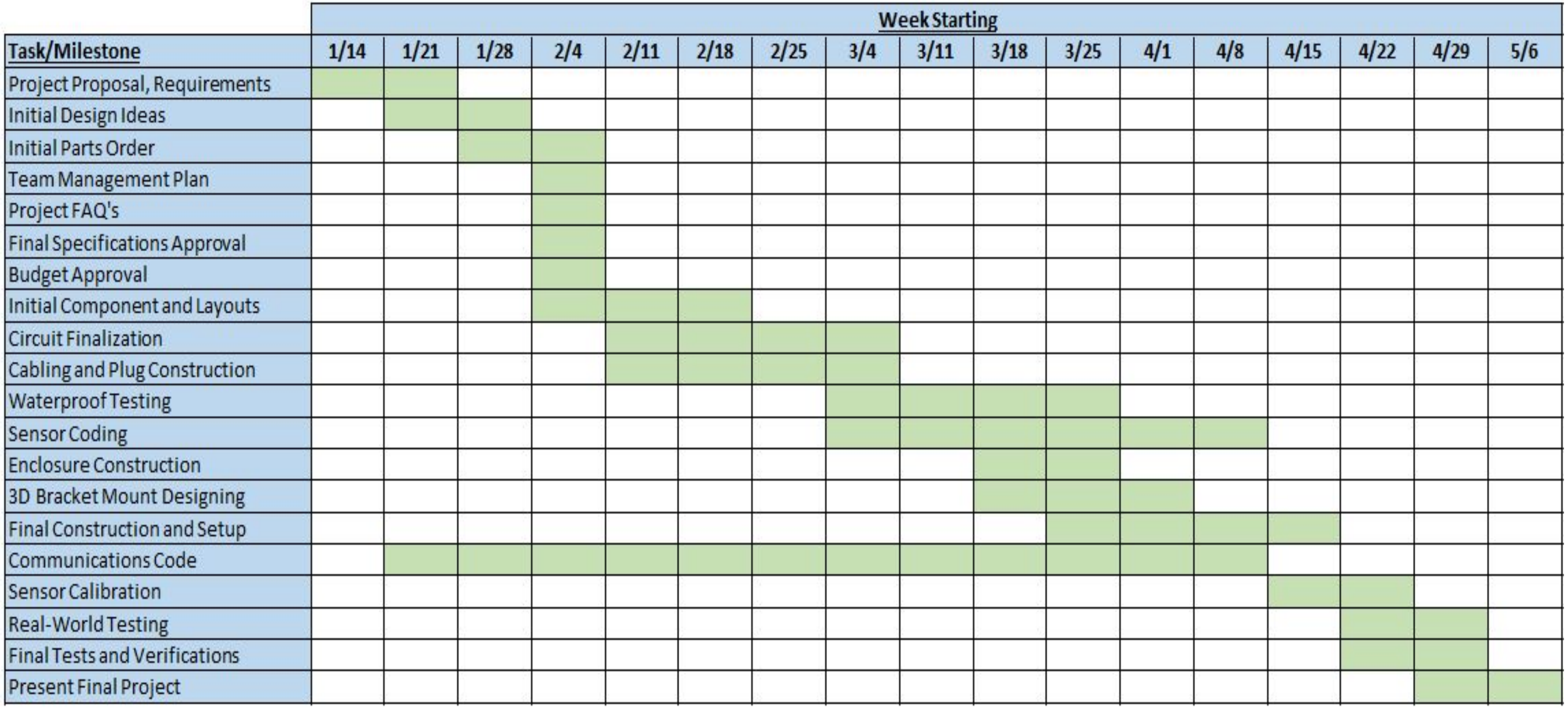


Budget

- Given $1000 for entire project
- Cost per sensor = $88.96 each for 1 unit, $53.78 each for 100 units

Subsystem	Amount Spent
Housing, Cabling, and Waterproofing	$125
Test Equipment	$300
Circuit Design Components	$200
Integrated Circuits and Microprocessors	$125
Total	**$750**

Overall Timeline



Questions?