Real-Time Subsea Turbulence and Sediment Monitoring System

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ECED4402 - Real Time Systems

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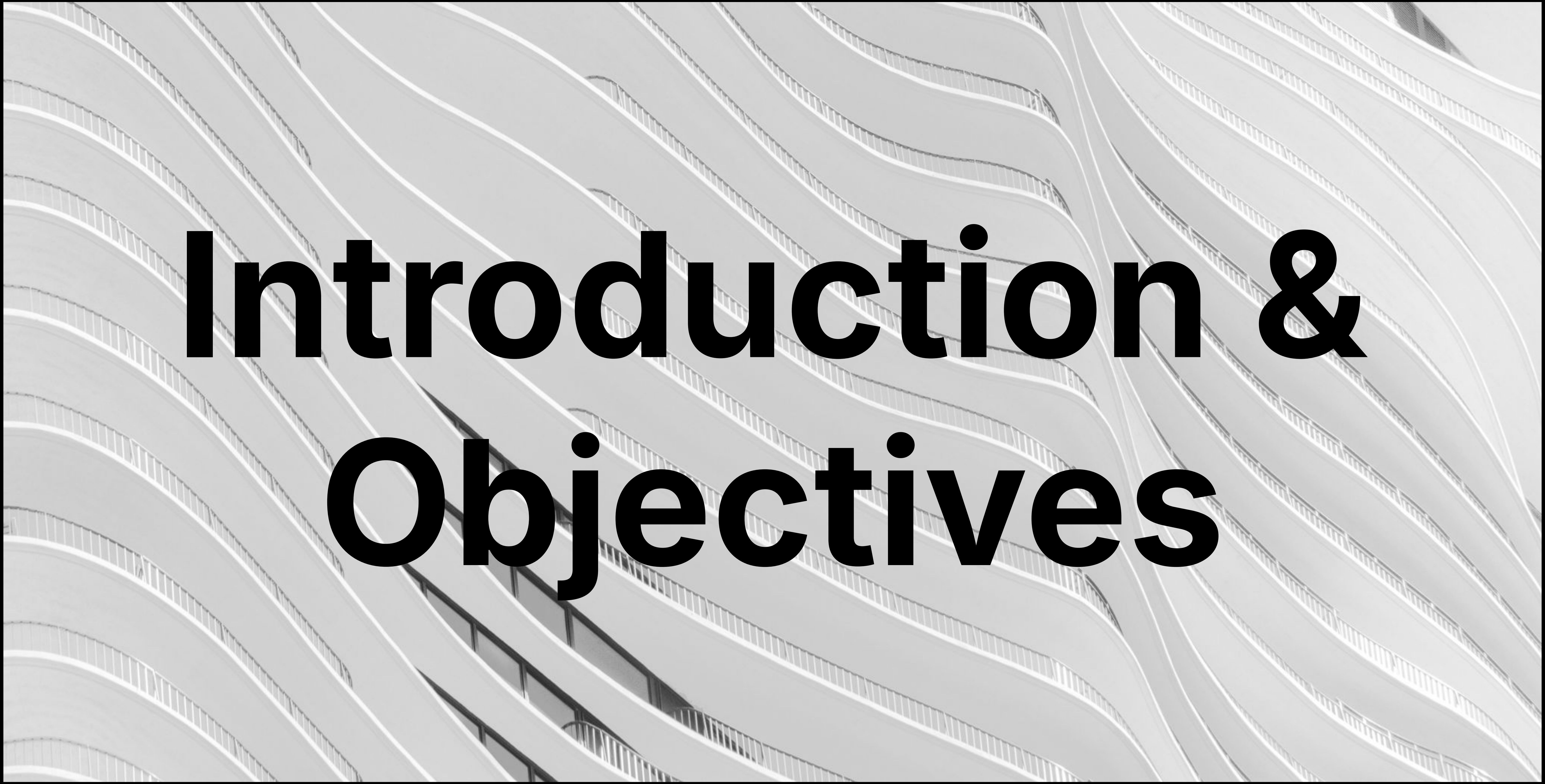


Introduction & Objectives

Problem Statement

Current Challenges

- Inefficient monitoring of underwater sediment levels and turbulence
- Delayed detection of potential environmental hazards
- Limited real-time data collection capabilities

Requirements

- Deployable, low cost, low power, and durable real-time monitoring system using multiple sensors
- Automated alert system for threshold violations
- Reliable underwater data transmission
- Real time live/updating graphing capabilities

Impact, Limitations and Benefits

Environmental Impact

- Sediment accumulation affects marine ecosystems
- Turbulence disrupts underwater habitats
- Early detection prevents long-term damage

Current Limitations

- Manual monitoring is time consuming, redundant and expensive.
- Delayed response to critical changes
- Limited real-time data availability

Proposed Benefits

- Real-time environmental monitoring
- Automated alert system
- Cost-effective solution
- Low Power (Environmentally friendly)
- Includes features to facilitate quick analysis

Project Objectives

Real-Time Data Collection

- Collect data from multiple underwater sensors simultaneously and transmit them
- Sample rates: every 200ms per sensor
- Process data within 500ms cycle time
- Update graph in real time to facilitate quick analysis and finding trends rapidly.

Environmental Monitoring

- Monitor turbulence levels using acoustic data
- Track sediment concentrations via pressure
- Measure water flow patterns

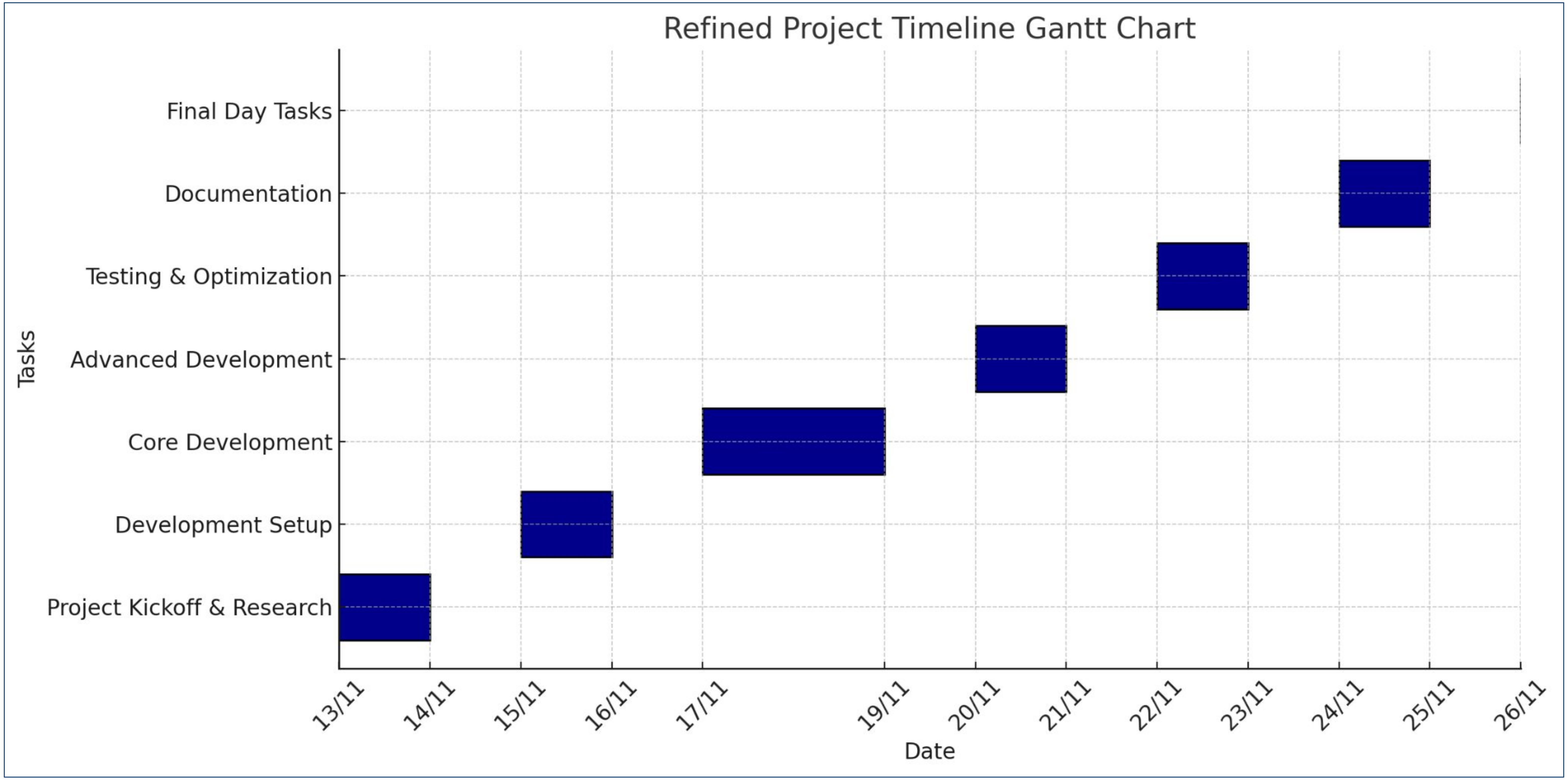
Alert System

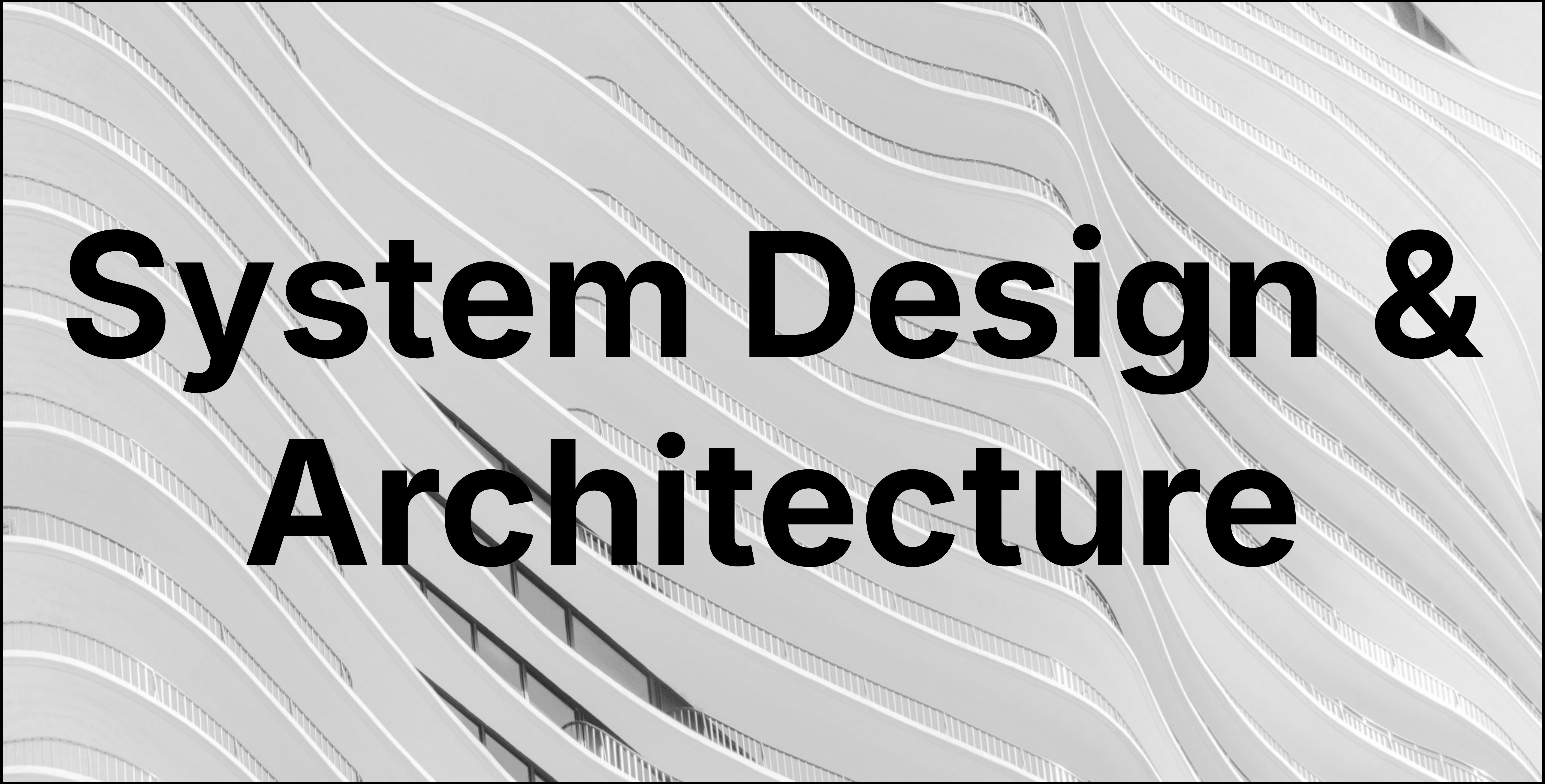
- Define critical thresholds for each parameter
- Implement priority-based alert system

System Performance

- Ensure data transmission and sensor reliability
- Low Cost System
- Low Power and should be able to operate in prolonged periods of times (5 days in our use case).

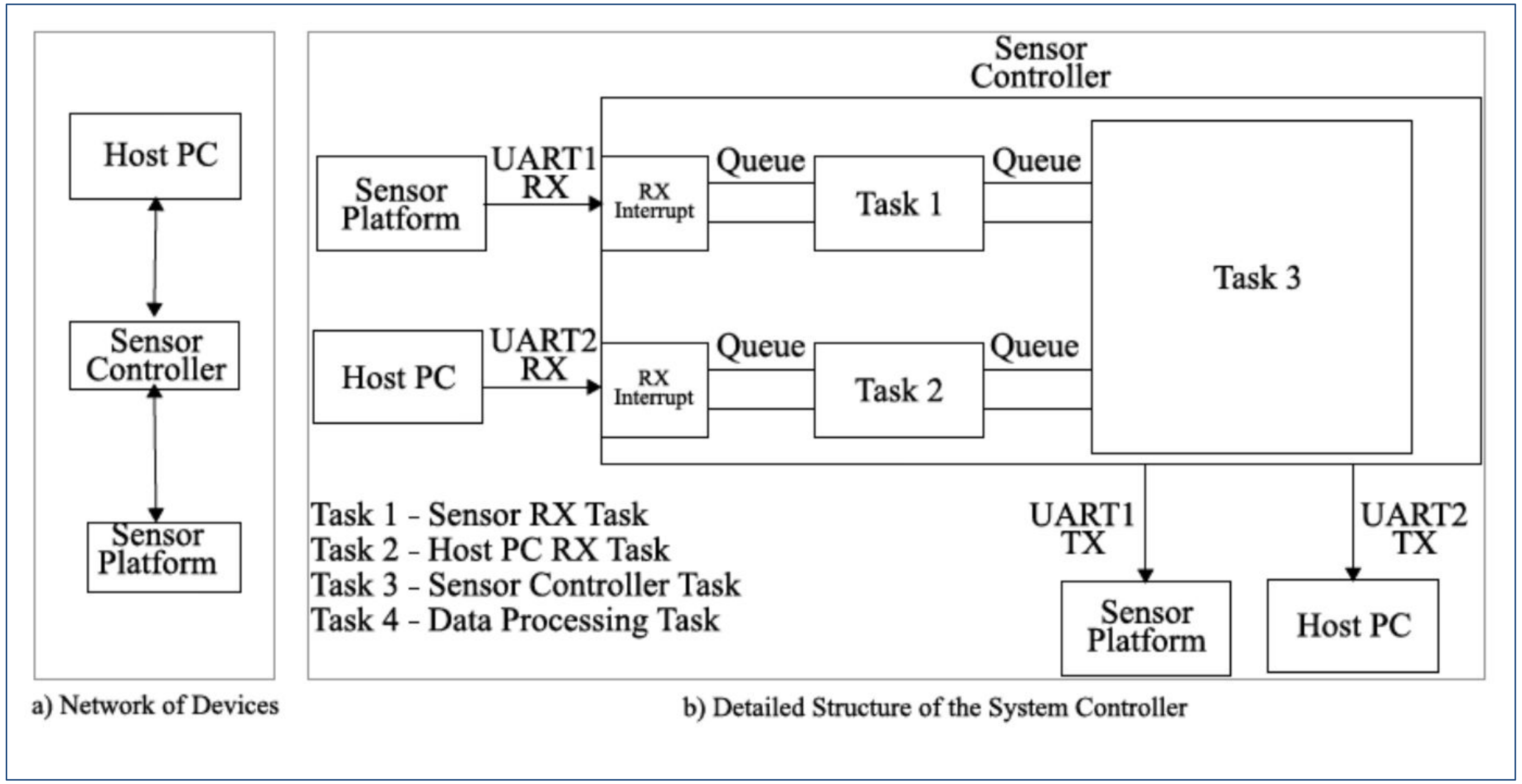
Project Timeline





System Design & Architecture

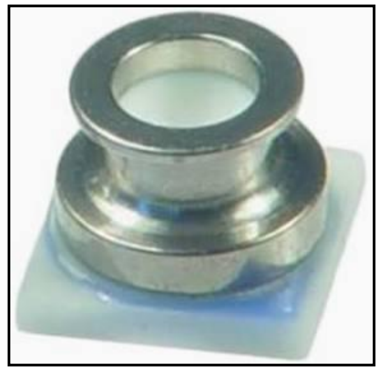
High Level Architecture Overview

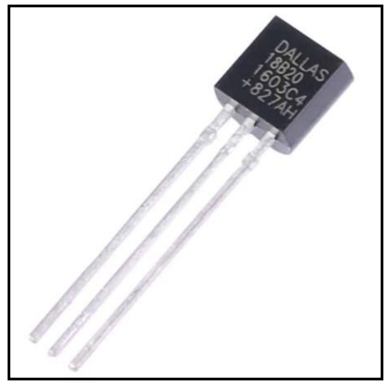


Task 1 - Sensor RX Task
Task 2 - Host PC RX Task
Task 3 - Sensor Controller Task
Task 4 - Data Processing Task

a) Network of Devices

b) Detailed Structure of the System Controller





Hardware Components

Core System
- STM32F411 Microcontroller
- Power Bank (6000mAH)
- USART Communication

Sensors
- MS5837 Pressure Sensor
- SEN-HZ21WA Flow Sensor
- HTI-96MIN Acoustic Sensor
- DS18B20 Temperature Sensor

Software Structure

FreeRTOS Tasks
- Sensor Data Acquisition
- Data Processing
- Alert Generation
- Communication Control

Communication Protocol
- UART1: Sensor Platform
- UART2: Host PC Interface
- Queue-based Data Management

Power Requirements Analysis

Sensor Current Draw

MS5837 Pressure Sensor:1.2mA @ 3.3V

SEN-HZ21WA Flow Sensor:15mA @ 3.3V

HTI-96MIN Acoustic Sensor:2-3mA @ 3.3V

DS18B20 Temperature Sensor:0.5mA @ 3.3V

System Requirements

Microcontroller Base: 30mA @ 5V

Total Sensor Array: 20mA @ 3.3V

Total System Current: ~50mA

Power Solution

Battery Requirements

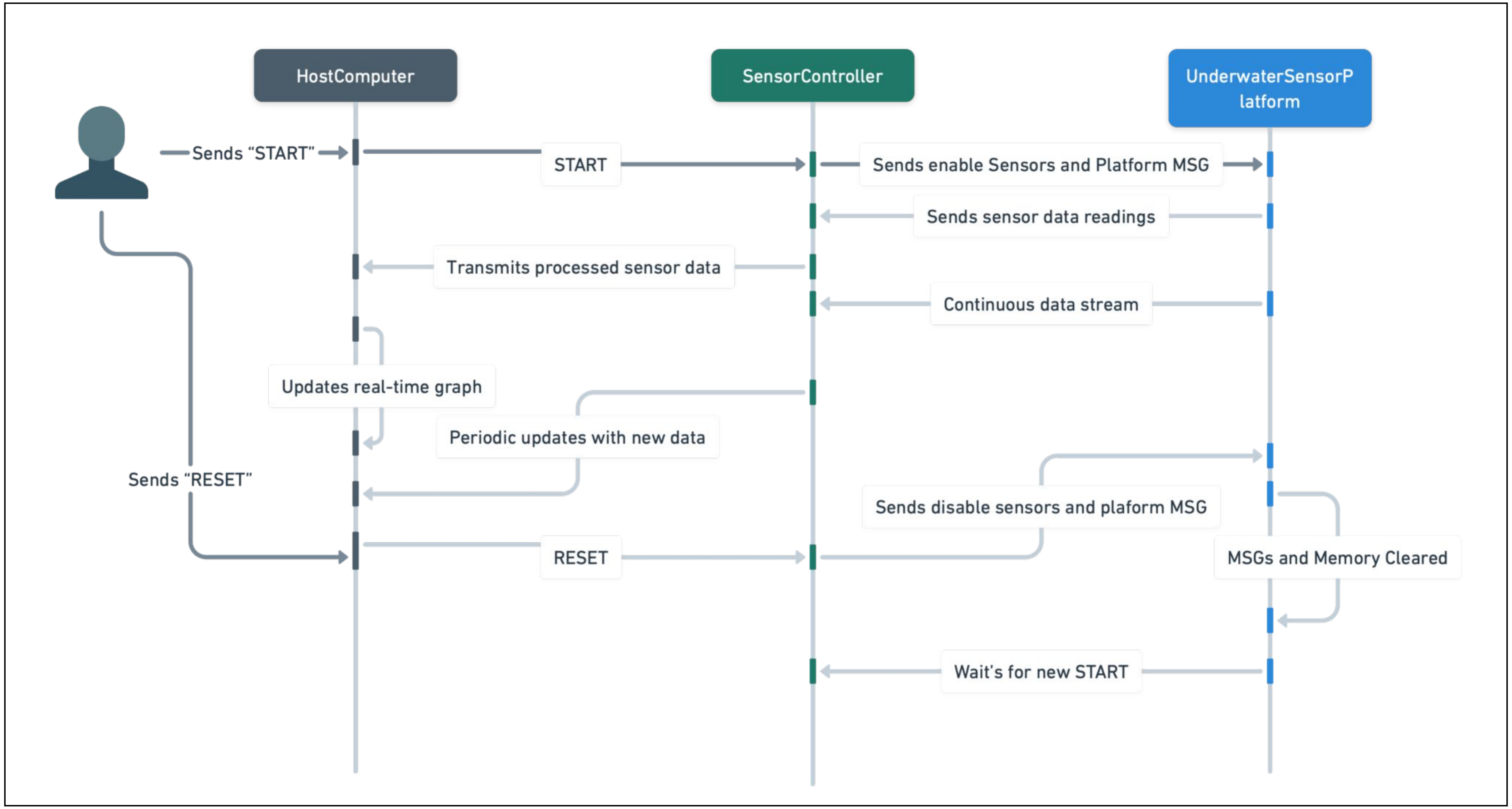
- Capacity: 6000mAH minimum
- Voltage: 5V output
- Weekly maintenance schedule

Operational Time

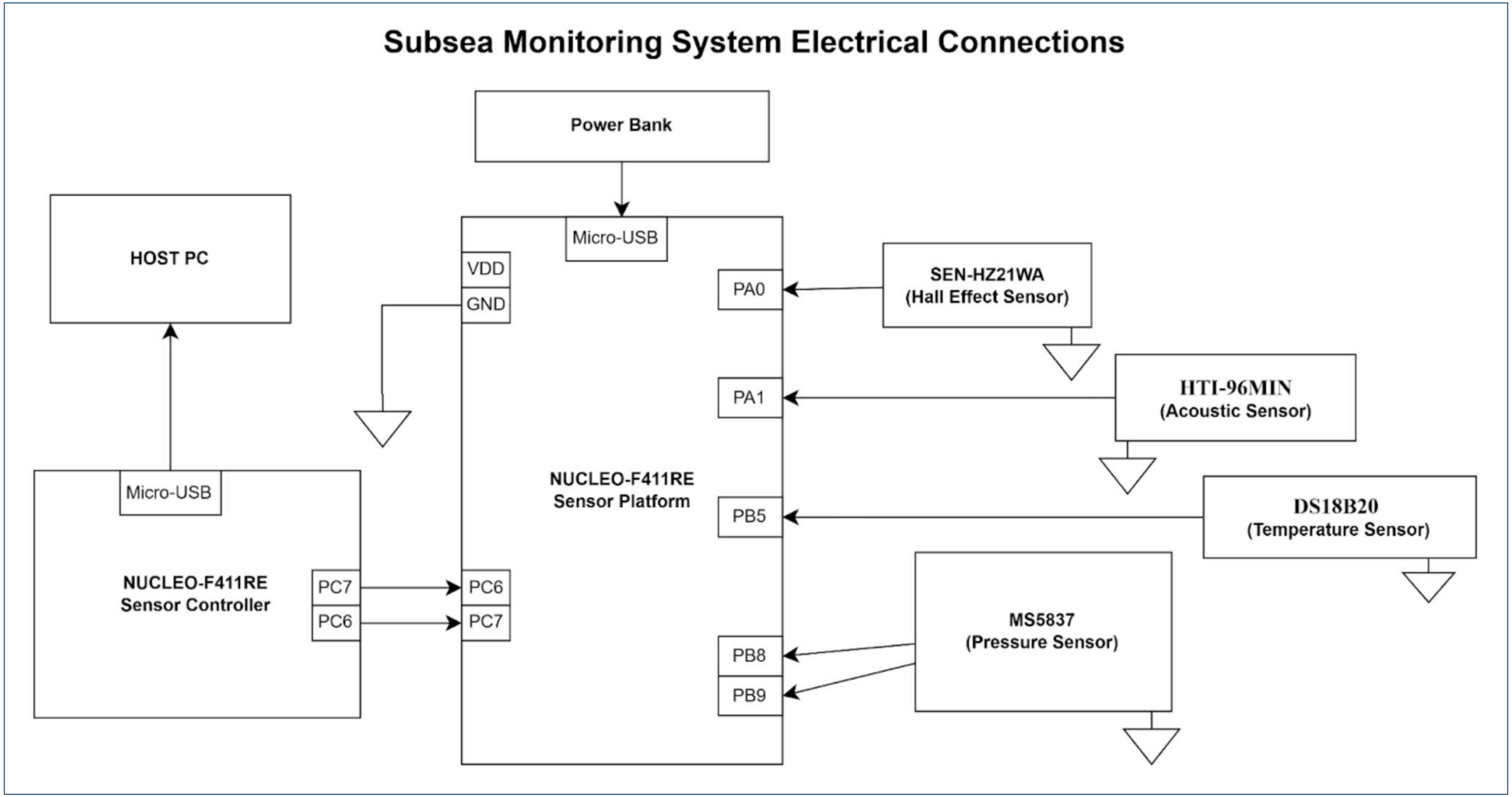
- 5 days continuous operation
- Safety margin included
- Easy battery replacement

High Level Architecture Overview - continued

System Structure/Flow Diagram



Electrical Connections



Subsea Monitoring System Electrical Connections

Power Bank

HOST PC

Micro-USB

VDD

GND

NUCLEO-F411RE
Sensor Platform

PA0

PA1

PB5

PB8

PB9

PC6

PC7

Micro-USB

NUCLEO-F411RE
Sensor Controller

PC7

PC6

SEN-HZ21WA
(Hall Effect Sensor)

HTI-96MIN
(Acoustic Sensor)

DS18B20
(Temperature Sensor)

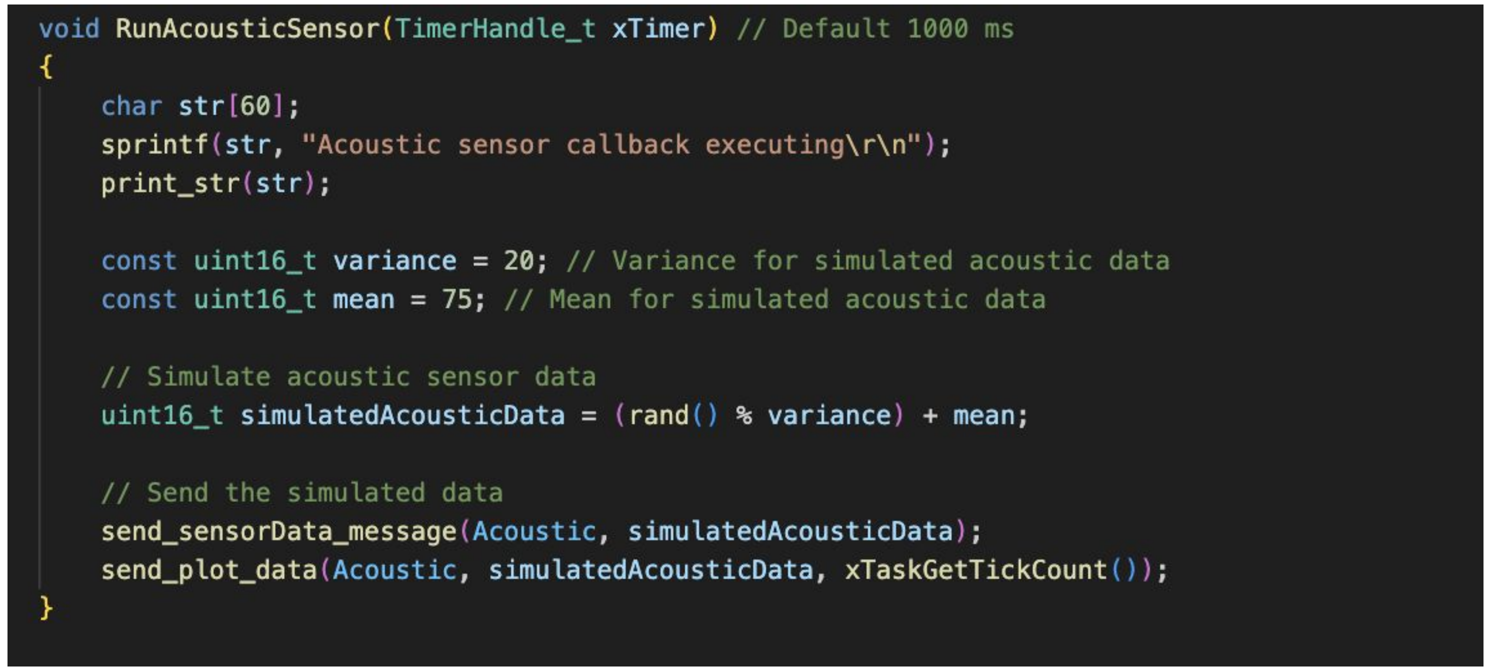
MS5837
(Pressure Sensor)

Estimated Cost

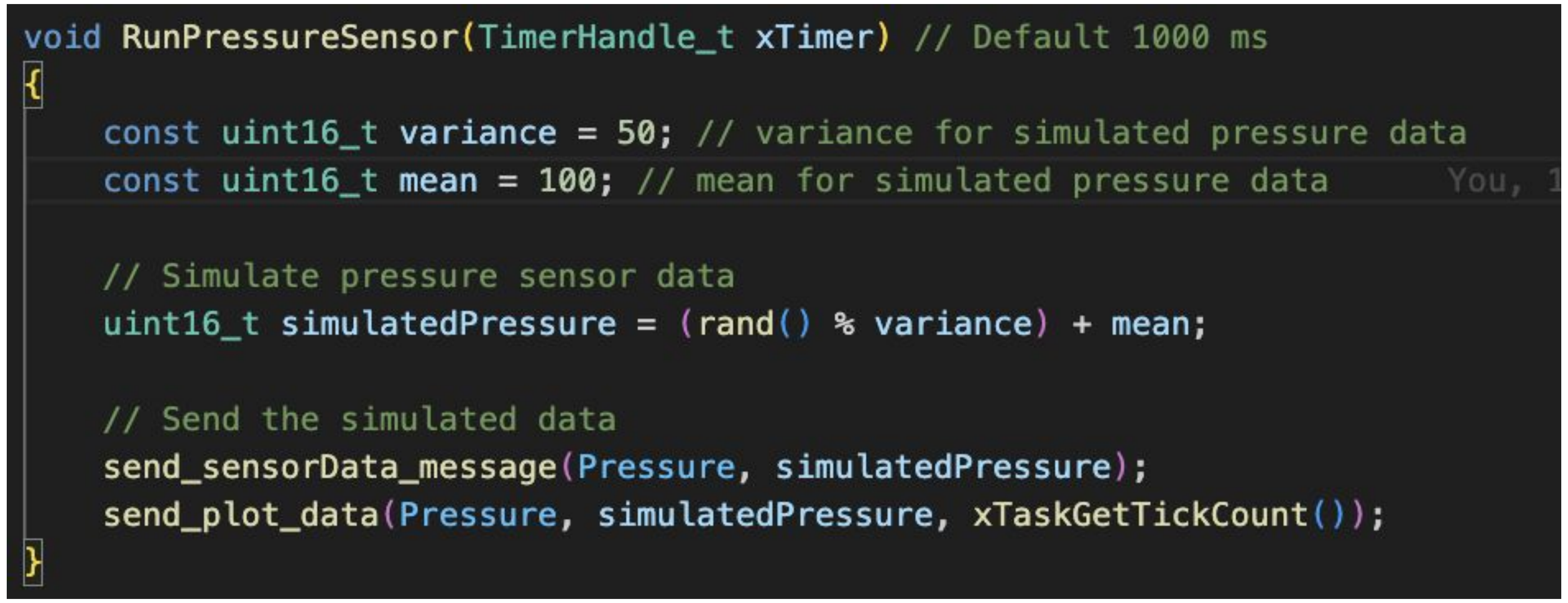
Component	Estimated Cost ($)	Source
2 * STM32F411 Nucleo-64 Development Board	2 * 20.00	https://www.mouser.ca/ProductDetail/STMicroelectronics/NUCLEO-F411RE?qs=Zt3UNFD9mQjdEJg18RwZ2g%3D%3D&mgh=1&utm_id=17633666059&gad_source=1&gbraid=0AAAAADn_wf2qVtMJIPtzoeIIrPSLAM-KV&gclid=Cj0KCQiAgJa6BhCOARIsAMiL7V9GoYGCXgn6gLJ6WoDUrmJEPP6DcDU5BDMRFTrME9zbNv0nHLSfgawaApmHEALw_wcB
MS5837-30BA Pressure Sensor	20.00	https://www.mouser.ca/ProductDetail/Measurement-Specialties/MS583730BA01-50?qs=SvmF4ZFxmIz%2F53mFym%252BZPQ%3D%3D&mgh=1&utm_id=17633666059&gad_source=1&gbraid=0AAAAADn_wf2qVtMJIPtzoeIIrPSLAM-KV&gclid=Cj0KCQiAgJa6BhCOARIsAMiL7V_umHu74A3CdgIPyKfRgGTSLH8Ar--DTOAfYn9ZR0NIunyssYn-7EIaAnoiEALw_wcB
SEN-HZ21WA Flow Rate Sensor	14.00	https://www.mouser.ca/ProductDetail/Seeed-Studio/314150005?qs=SEIPoaY2y5IMuXe9y0k8Qw%3D%3D&mgh=1&utm_id=17633666059&gad_source=1&gbraid=0AAAAADn_wf2qVtMJIPtzoeIIrPSLAM-KV&gclid=Cj0KCQiAgJa6BhCOARIsAMiL7V9ovAG01tCd5FMG26nKOqyo-_yl90xvLeUmkhoFduXwdBmTd19I-IAaAsRNEALw_wcB
HTI-96-MIN Hydrophone Acoustic Sensor	100.00	N/A
DS18B20 Temperature Sensor	11.00	https://www.mouser.ca/ProductDetail/Analog-Devices-Maxim-Integrated/DS18B20+PAR?qs=0Y9aZN%252BMVCWPX1JasrnMQg%3D%3D&mgh=1&utm_id=17633666059&gad_source=1&gbraid=0AAAAADn_wf2qVtMJIPtzoeIIrPSLAM-KV&gclid=Cj0KCQiAgJa6BhCOARIsAMiL7V8YLQwlh8yO57g0iZqUsXniNEEcXG7Emv10JMp3ORJZfLsin-rsubQaAp8DEALw_wcB
Power Bank (6000mAh)	07.00	https://www.canadacomputers.com/en/power-banks/130514/orico-6000mah-power-bank-for-smart-phone-white-orico-firefly-m6-wh-pro.html
Waterproof Enclosure	30.00	N/A
Miscellaneous (Cables, Connectors, etc.)	20.00	N/A
Total Estimated Cost	**242.00**	

Data Acquisition & Processing

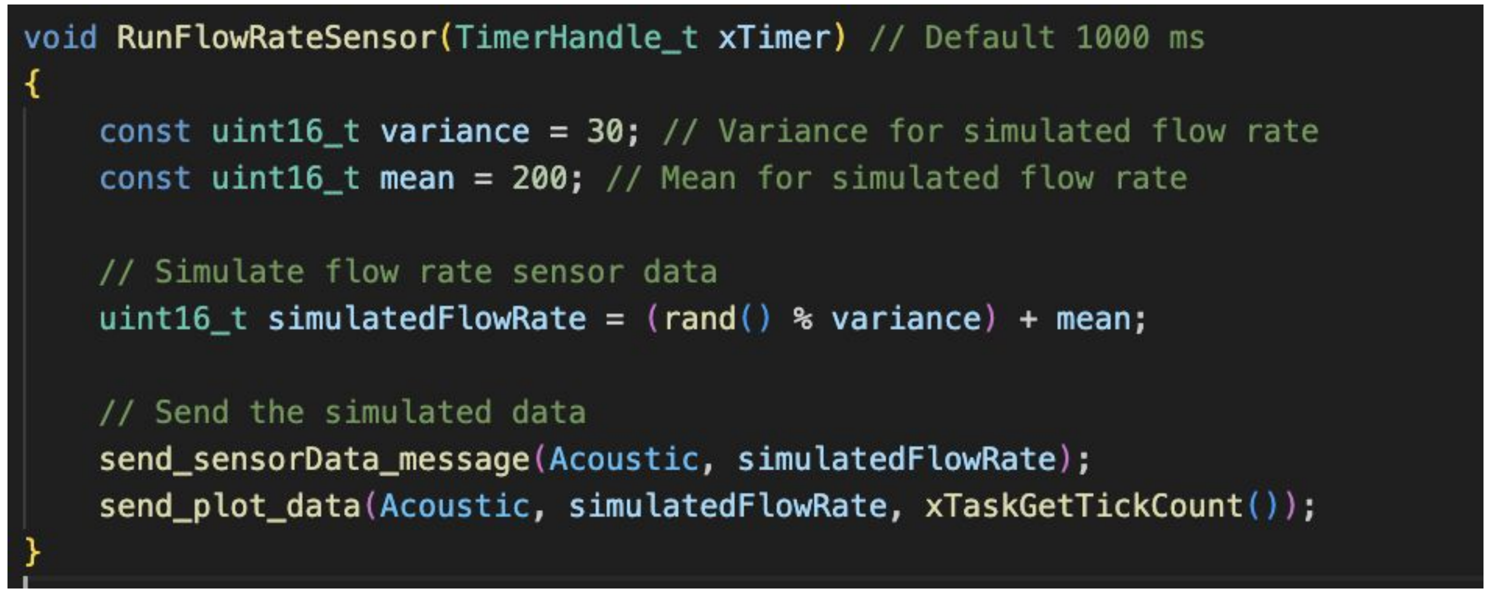
Since we couldn’t actually install the sensors to our system, we used the following functions to test by using random values that are within the range we expect to obtain when system is deployed underwater.



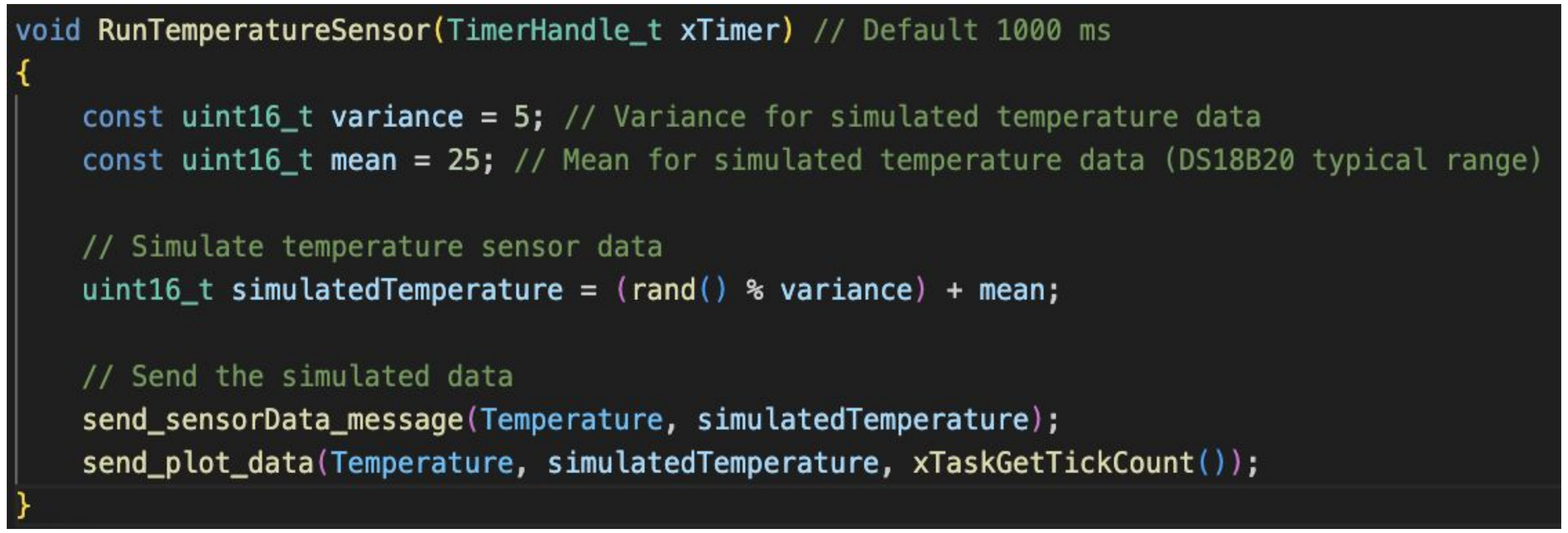
```
void RunAcousticSensor(TimerHandle_t xTimer) // Default 1000 ms
{
    char str[60];
    sprintf(str, "Acoustic sensor callback executing\r\n");
    print_str(str);

    const uint16_t variance = 20; // Variance for simulated acoustic data
    const uint16_t mean = 75; // Mean for simulated acoustic data

    // Simulate acoustic sensor data
    uint16_t simulatedAcousticData = (rand() % variance) + mean;

    // Send the simulated data
    send_sensorData_message(Acoustic, simulatedAcousticData);
    send_plot_data(Acoustic, simulatedAcousticData, xTaskGetTickCount());
}
```



```
void RunPressureSensor(TimerHandle_t xTimer) // Default 1000 ms
{
    const uint16_t variance = 50; // variance for simulated pressure data
    const uint16_t mean = 100; // mean for simulated pressure data      You, 1

    // Simulate pressure sensor data
    uint16_t simulatedPressure = (rand() % variance) + mean;

    // Send the simulated data
    send_sensorData_message(Pressure, simulatedPressure);
    send_plot_data(Pressure, simulatedPressure, xTaskGetTickCount());
}
```



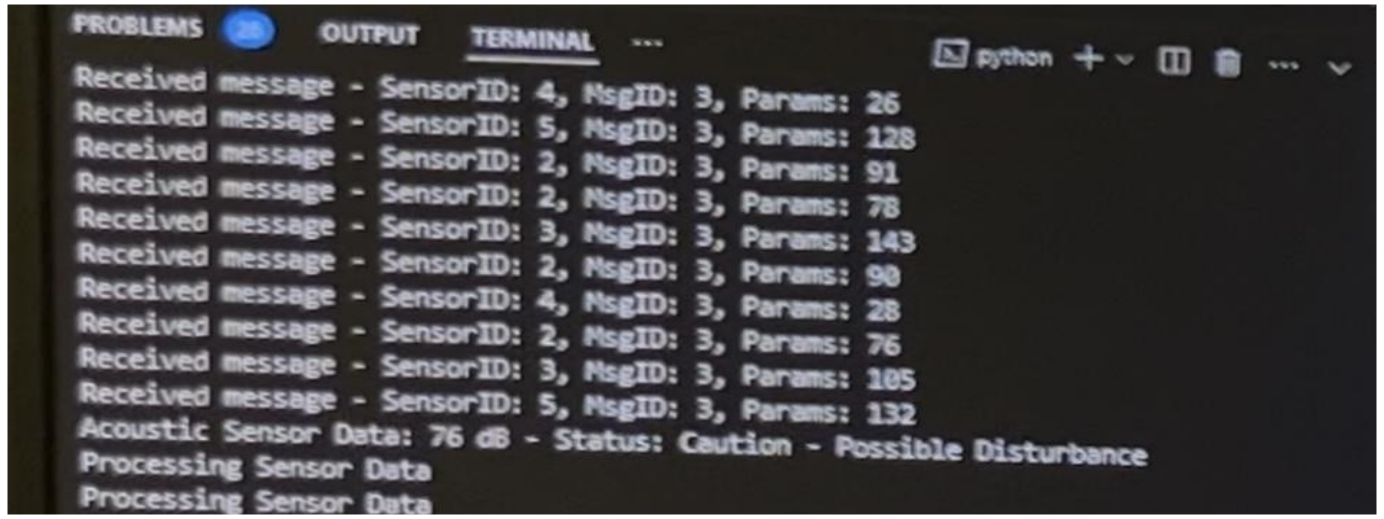
```
void RunFlowRateSensor(TimerHandle_t xTimer) // Default 1000 ms
{
    const uint16_t variance = 30; // Variance for simulated flow rate
    const uint16_t mean = 200; // Mean for simulated flow rate

    // Simulate flow rate sensor data
    uint16_t simulatedFlowRate = (rand() % variance) + mean;

    // Send the simulated data
    send_sensorData_message(Acoustic, simulatedFlowRate);
    send_plot_data(Acoustic, simulatedFlowRate, xTaskGetTickCount());
}
```



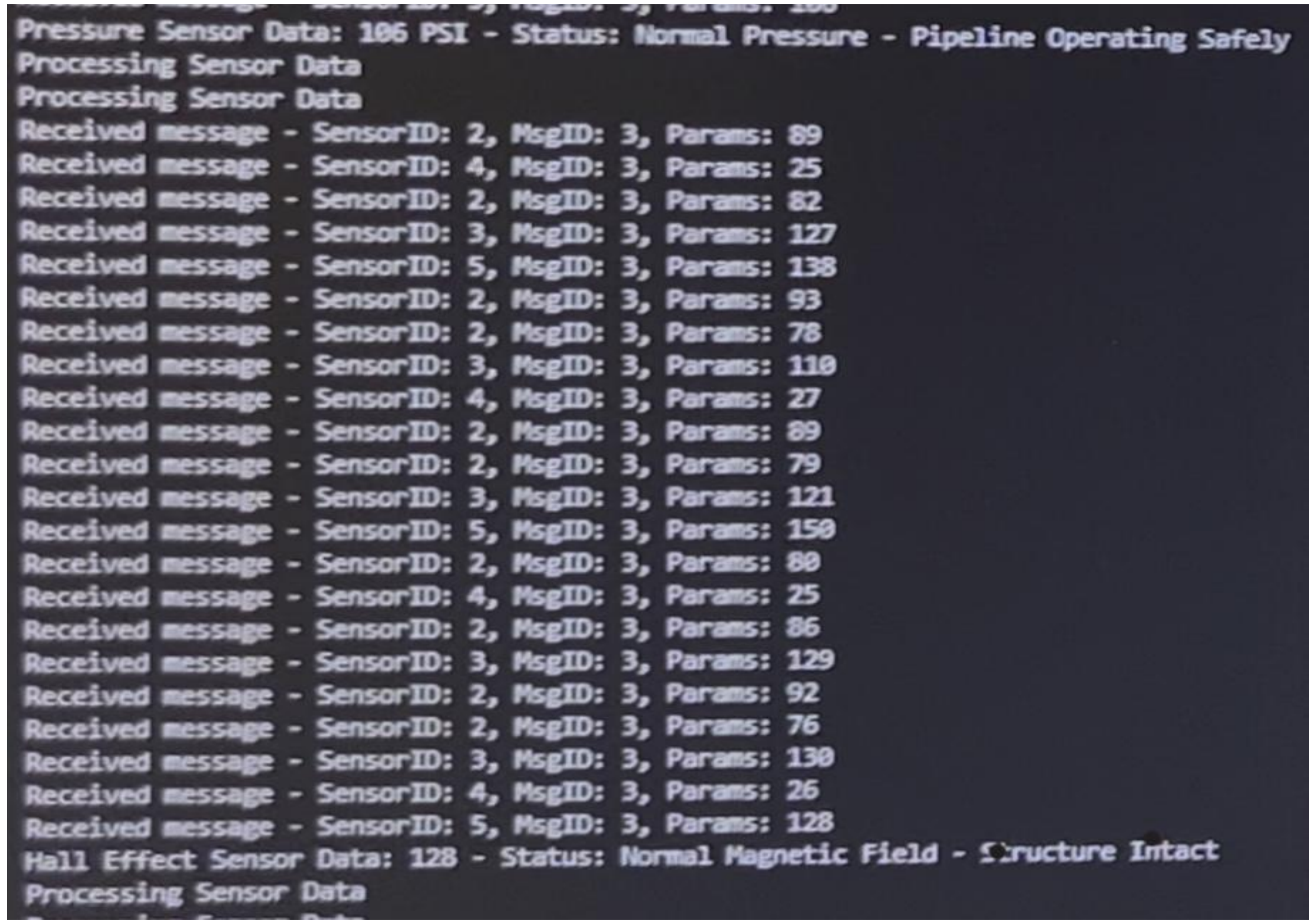
```
void RunTemperatureSensor(TimerHandle_t xTimer) // Default 1000 ms
{
    const uint16_t variance = 5; // Variance for simulated temperature data
    const uint16_t mean = 25; // Mean for simulated temperature data (DS18B20 typical range)

    // Simulate temperature sensor data
    uint16_t simulatedTemperature = (rand() % variance) + mean;

    // Send the simulated data
    send_sensorData_message(Temperature, simulatedTemperature);
    send_plot_data(Temperature, simulatedTemperature, xTaskGetTickCount());
}
```

Results

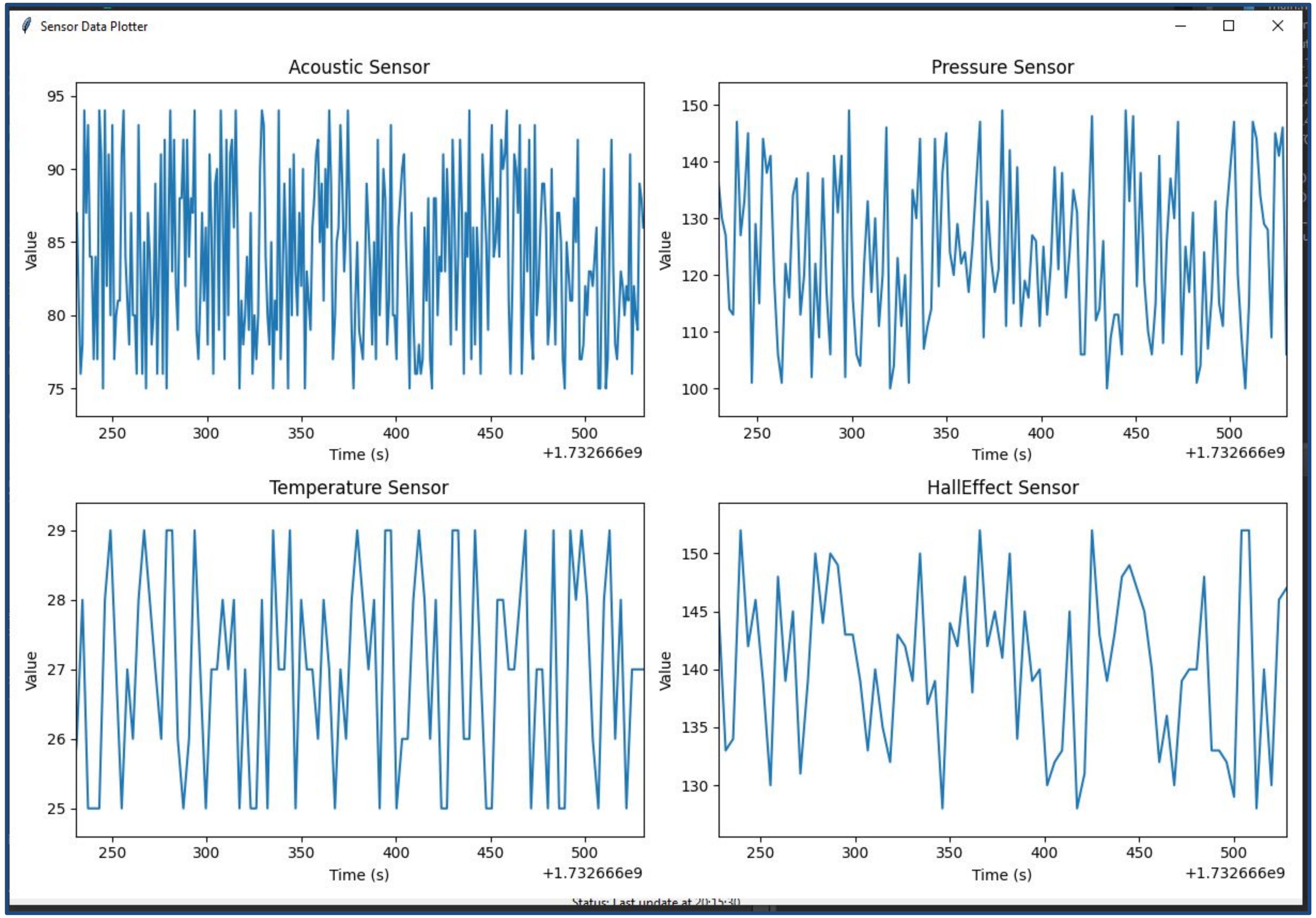
System Results

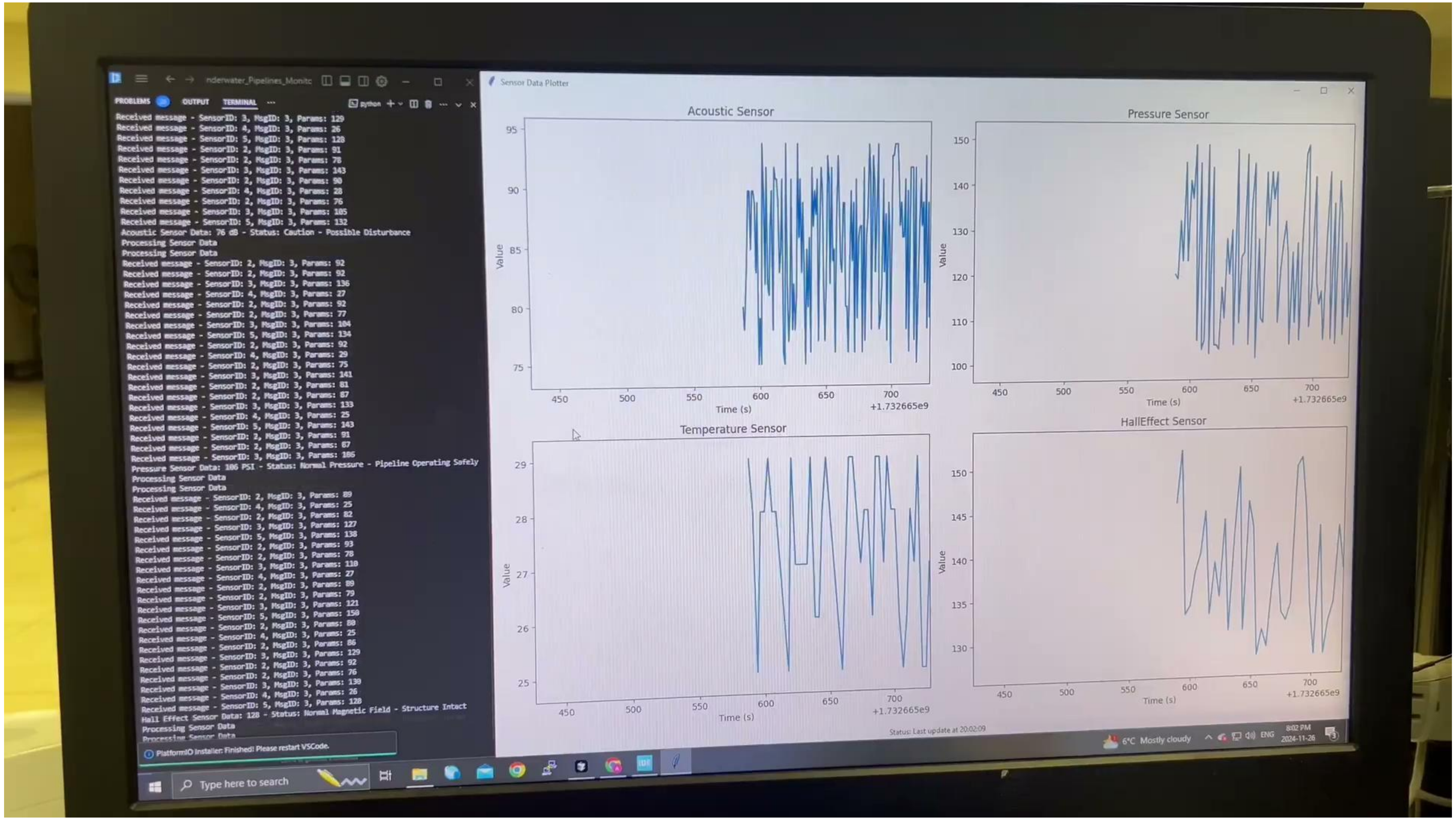


```
Received message - SensorID: 4, MsgID: 3, Params: 26
Received message - SensorID: 5, MsgID: 3, Params: 128
Received message - SensorID: 2, MsgID: 3, Params: 91
Received message - SensorID: 2, MsgID: 3, Params: 78
Received message - SensorID: 3, MsgID: 3, Params: 143
Received message - SensorID: 2, MsgID: 3, Params: 90
Received message - SensorID: 4, MsgID: 3, Params: 28
Received message - SensorID: 2, MsgID: 3, Params: 76
Received message - SensorID: 3, MsgID: 3, Params: 105
Received message - SensorID: 5, MsgID: 3, Params: 132
Acoustic Sensor Data: 76 dB - Status: Caution - Possible Disturbance
Processing Sensor Data
Processing Sensor Data
```



```
Pressure Sensor Data: 106 PSI - Status: Normal Pressure - Pipeline Operating Safely
Processing Sensor Data
Processing Sensor Data
Received message - SensorID: 2, MsgID: 3, Params: 89
Received message - SensorID: 4, MsgID: 3, Params: 25
Received message - SensorID: 2, MsgID: 3, Params: 82
Received message - SensorID: 3, MsgID: 3, Params: 127
Received message - SensorID: 5, MsgID: 3, Params: 138
Received message - SensorID: 2, MsgID: 3, Params: 93
Received message - SensorID: 2, MsgID: 3, Params: 78
Received message - SensorID: 3, MsgID: 3, Params: 110
Received message - SensorID: 4, MsgID: 3, Params: 27
Received message - SensorID: 2, MsgID: 3, Params: 89
Received message - SensorID: 2, MsgID: 3, Params: 79
Received message - SensorID: 3, MsgID: 3, Params: 121
Received message - SensorID: 5, MsgID: 3, Params: 150
Received message - SensorID: 2, MsgID: 3, Params: 80
Received message - SensorID: 4, MsgID: 3, Params: 25
Received message - SensorID: 2, MsgID: 3, Params: 86
Received message - SensorID: 3, MsgID: 3, Params: 129
Received message - SensorID: 2, MsgID: 3, Params: 92
Received message - SensorID: 2, MsgID: 3, Params: 76
Received message - SensorID: 3, MsgID: 3, Params: 130
Received message - SensorID: 4, MsgID: 3, Params: 26
Received message - SensorID: 5, MsgID: 3, Params: 128
Hall Effect Sensor Data: 128 - Status: Normal Magnetic Field - Structure Intact
Processing Sensor Data
```





```
Received message - SensorID: 3, MsgID: 3, Params: 129
Received message - SensorID: 4, MsgID: 3, Params: 26
Received message - SensorID: 5, MsgID: 3, Params: 128
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Received message - SensorID: 2, MsgID: 3, Params: 76
Received message - SensorID: 3, MsgID: 3, Params: 105
Received message - SensorID: 5, MsgID: 3, Params: 132
Acoustic Sensor Data: 76 dB - Status: Caution - Possible Disturbance
Processing Sensor Data
Processing Sensor Data
Received message - SensorID: 2, MsgID: 3, Params: 92
Received message - SensorID: 2, MsgID: 3, Params: 92
Received message - SensorID: 3, MsgID: 3, Params: 136
Received message - SensorID: 4, MsgID: 3, Params: 27
Received message - SensorID: 2, MsgID: 3, Params: 92
Received message - SensorID: 2, MsgID: 3, Params: 77
Received message - SensorID: 3, MsgID: 3, Params: 104
Received message - SensorID: 5, MsgID: 3, Params: 134
Received message - SensorID: 2, MsgID: 3, Params: 92
Received message - SensorID: 4, MsgID: 3, Params: 29
Received message - SensorID: 2, MsgID: 3, Params: 75
Received message - SensorID: 3, MsgID: 3, Params: 141
Received message - SensorID: 2, MsgID: 3, Params: 81
Received message - SensorID: 2, MsgID: 3, Params: 87
Received message - SensorID: 3, MsgID: 3, Params: 133
Received message - SensorID: 4, MsgID: 3, Params: 25
Received message - SensorID: 5, MsgID: 3, Params: 143
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Received message - SensorID: 2, MsgID: 3, Params: 87
Received message - SensorID: 3, MsgID: 3, Params: 106
Pressure Sensor Data: 106 PSI - Status: Normal Pressure - Pipeline Operating Safely
Processing Sensor Data
Processing Sensor Data
Received message - SensorID: 2, MsgID: 3, Params: 89
Received message - SensorID: 4, MsgID: 3, Params: 25
Received message - SensorID: 2, MsgID: 3, Params: 82
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Received message - SensorID: 5, MsgID: 3, Params: 138
Received message - SensorID: 2, MsgID: 3, Params: 93
Received message - SensorID: 2, MsgID: 3, Params: 78
Received message - SensorID: 3, MsgID: 3, Params: 118
Received message - SensorID: 4, MsgID: 3, Params: 27
Received message - SensorID: 2, MsgID: 3, Params: 89
Received message - SensorID: 2, MsgID: 3, Params: 79
Received message - SensorID: 3, MsgID: 3, Params: 121
Received message - SensorID: 5, MsgID: 3, Params: 150
Received message - SensorID: 2, MsgID: 3, Params: 88
Received message - SensorID: 4, MsgID: 3, Params: 25
Received message - SensorID: 2, MsgID: 3, Params: 86
Received message - SensorID: 3, MsgID: 3, Params: 129
Received message - SensorID: 2, MsgID: 3, Params: 92
Received message - SensorID: 2, MsgID: 3, Params: 76
Received message - SensorID: 3, MsgID: 3, Params: 130
Received message - SensorID: 4, MsgID: 3, Params: 26
Received message - SensorID: 5, MsgID: 3, Params: 128
Hall Effect Sensor Data: 128 - Status: Normal Magnetic Field - Structure Intact
Processing Sensor Data
Processing Sensor Data
```

PlatformIO Installer: Finished! Please restart VSCode.

Status: Last update at 20:02:09

Future Considerations

- Add multiple sensors and algorithms to detect faulty sensors/errors.
- Include wireless/remote connection options.
- Incorporate a better user friendly front end dashboard and pages.
- Support different data logging and export methods (.csv, JSON etc) to increase graph ranges, save dataset.
- Add check to insure saved data is “clean” and free from anomalies due to sensor errors etc.
- Add predictive algorithms (ML) to analyze and predict changes in data in real time based on previous data entry.

Questions