Conceptual Design

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I. Introduction

Houses face many types of issues like gas leaks, fires, floods, and mold, which cause damage to the house leading to a decrease in value [1]–[3]. Unlike a smartphone or a modern car, current house constructions lack a mechanism to detect and monitor this information. This information, such as knowing if water damage has occurred, could improve the value of the house by proving that issues have not occurred or were taken care of quickly by the homeowner. To detect and monitor all of these problems, this project proposes a collection of sensors and a head unit, called Preserve Home Pro. The goal of the system is to measure, record, and display important active and historical data, giving a homeowner valuable information to help maintain and protect the value of their home. The Preserve Home Pro will be designed as a semi-permanent system that will last for up to thirty years. The system will also communicate information through a closed network without requiring the Internet. Combining these concepts, this project proposes an advanced solution to house health monitoring.

A current market for this type of system does not exist. Although there are several devices available to detect specific problems, none of this technology is integrated as a single system in houses today. Since many homes face issues with gas leaks, fires, floods, and mold, actively detecting these issues could be beneficial in preserving a home's value [1]–[3]. In summary, The Preserve Home Pro will be designed as a semi-permanent system with multiple sensor modules that would detect and log these threats to a house, potentially increasing the value of a home.

This document is important in the design process because it will present general solutions based on the specifications and constraints stated in the project proposal. The document will also explain what each subsystem will do and give a more detailed description of the subsystem as a whole. Expanding on each subsystem will give the team an easier understanding of the problem and the proposed solution.

A. Specifications & Constraints

Stated below is a full list of the shall statements for the project placed in number order to be referenced (SC#) later in the document.

1) The Head unit shall know what sensor is sending data to it, the sensor's location, and be able to differentiate from other sensors. This originated from the team supervisor.
2) The Head unit shall be able to display and log active and historical data from sensors. This originated from the project team and team supervisor.
3) Head unit shall be able to detect if the fire module temperature is at 176 degrees Fahrenheit or higher and display a warning [4]. This originated from the project team based on the ignition temperature of drywall.
4) The Head unit shall be able to receive data from the water module to display a warning if water is present and the total water depth. This originated from the project team.
5) Head unit shall receive data from the gas module and follow OSHA standards for ammonia, propane, and carbon oxides (50 ppm, 1000 ppm, and 50 ppm respectively over an eight-hour window) [5]. This originated from the OSHA standards for the project.
6) Head unit shall be able to interpret, from the received data, that mold could form if the humidity levels exceed 50% and temperatures range between 55 degrees and 85 degrees Fahrenheit for a minimum of two days [6]. This originated from the project team based on the conditions in which mold can grow.
7) Head unit shall be able to receive the sensor name, number, data type, and raw data. This originated from the team supervisor.
8) System shall be primarily powered from the house's 120 V power supply. This originated from the project team.
9) Shall be a semi-permanent system that will last for up to thirty years. This originated from the team supervisor.
10) Shall have a backup power system that will allow the system to function in case of a primary power outage for up to two continuous weeks. This originated from both a standard and the team supervisor.
11) Shall fully function without regularly changing sensors or head unit batteries. This originated from all external stakeholders and the team supervisor.
12) Sensor modules shall not be placed in a way where they cannot wirelessly communicate with the system. This originated from the project team and broader implications.
13) Modules shall not be a distraction for a homeowner, and

not be directly visible. This originated from all external stakeholders and the team supervisor.

14) The Water module shall be able to detect multiple water levels and determine if water is present. This originated from the project team.
15) The Mold module shall be able to detect the current temperatures and humidity levels in an area and send it to the head unit. This originated from the project team.
16) The Gas module shall be able to detect ammonia, propane, and carbon oxide. This originated from the project team and the insurance companies.
17) The Fire module shall be able to detect the temperature of the sensor and send the data to the head unit. This originated from the project team.
18) System shall not require an internet connection to work and communicate with the head unit and sensors. This originated from homeowners, insurance agencies, and the team supervisor.
19) Sensor communication shall send the sensor name, number, data type, and raw data to the head unit. This originated from the project team.
20) System shall not collect additional data that is not required for sensor functionality. This originated from all internal and external stakeholders and from broader implications.
21) System shall follow all IEEE Code of Ethics and common standards. This originated from the IEEE Code of Ethics.

B. Standards

Listed below are the standards that the team follows directly correlated to the constraints:

IEEE Code of Ethics - This standard is a set of guidelines on how each team member will conduct themselves and hold the team accountable for the betterment of one another, the team, and the safety of the public. This standard is used to meet the ethics constraint [7] [SC21].

NFPA 70 (NEC), 2023 – Electrical standards – This standard will be a benchmark for safe electrical design, installation, and inspection to protect people and property from electrical hazards. This standard is used to meet the standards constraint. [8] [SC8].

IEEE 802, 2020 – Networking standards - a collection of networking standards that cover the physical and data link layer specifications for technologies such as Ethernet and wireless [9] [SC1, SC18, SC19].

Osha 1910.1000 Table Z-1 Air particulate standards - This standard is a metric for safe amounts of different air particulates in the air. This standard will ensure homeowners' safety from gasses like Ammonia, Propane, and Carbon Oxides [5] [SC5].

C. Ethical Considerations

The design team will follow all National Fire Protection Agency 70: National Electrical Code (NFPA 70) and Occupational Safety and Health Administration (OSHA) procedures [SC5]. The team will also follow all government laws stated by the United States of America Government. The team will also follow all IEEE Code of Ethics and common standards, like resistor color codes, communications between devices, and design schematics [SC21]. The team will legally use all copyrights, patents, and licenses when necessary. The system will be designed to prevent all risk and harm when operated by the user and not be a distraction [SC13].

D. Broader Considerations

Due to the limited time and budget allocated to this project, there are multiple broader implications. Broader implications are the potential effects that the system could cause. Firstly, it may interfere with nearby radio frequency devices. Secondly, there is a risk of fire if any of the backup batteries become damaged. Additionally, false positives may be triggered due to sensor wear or damage. Also, one concern from the stakeholders is unnecessary data recording and sharing. The system must not record conversations or cause any insecurities to the user [SC21]. Finally, given the installation process, it may be difficult to determine the level of effort required to maintain the sensors.

II. Block Diagram

The full detailed block diagram is pictured at the end of the document in figure 10.

A. Power System

The power system allows the Preserve Home Pro modules to function primarily on power from the house with a secondary backup battery in case of outages [SC8, SC10]. An uninterruptible power supply (UPS) will need to be implemented to allow the sensor modules to remain connected to the head unit. The use of a voltage regulator should also be installed to protect the hardware from power surges. A charging system for the battery will also be needed so users do not have to change out batteries [SC11]. This power system will allow the Preserve Home Pro to operate for up to 30 years [SC9].

Analytical Method: To ensure that the power system will work properly, calculations will be done to ensure the expected thirty-year life span. The wired aspect of the power system will have calculations that will prove that the house has enough power to provide for all of the sensor modules and the head unit. The backup power will have calculations to prove that the batteries that are being used will be able to stay on for a minimum of two weeks a year and have enough recharge cycles to last for up to thirty years. Also, a LTSpice simulation can be created to ensure the power system will work properly.

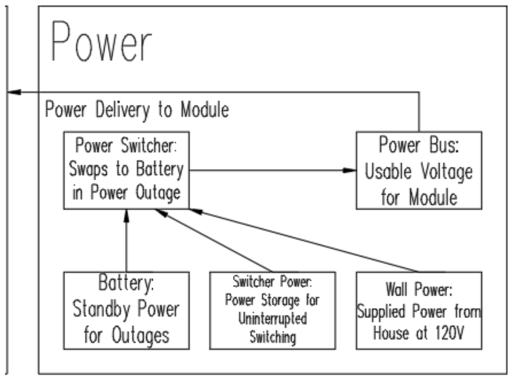

Fig. 1. Block Diagram of the Power System

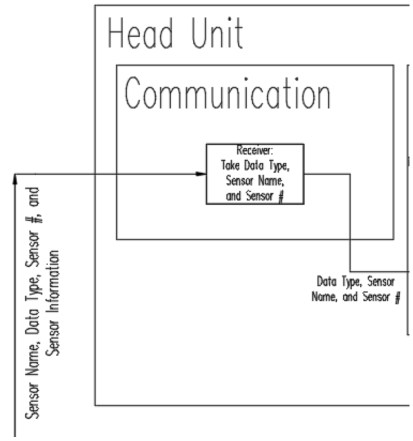

Fig. 3. Block Diagram for Communication System Receiver

B. Communication System

The Preserve Home Pro system uses wireless communication without an existing internet or WiFi connection in the house[SC18]. The transmission of the information from each module is used to record specific conditions of the house whether mold has grown, if water has accumulated, if gas is leaking, or if a fire has occurred. Preserve Home Pro needs to be able to transmit the information from each module[SC12]. The information transmitted from each module should include the name of the sensor, the number of the sensor, the data type, and the sensor information[SC19]. The sent information should be small enough in data size to allow for minimal to no processing from the modules. The sent information should also allow for the head unit to discern each module from the others to allow for data processing of multiple inputs.

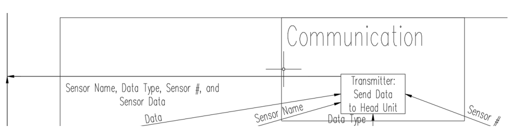

Fig. 2. Block Diagram for Communication System Transmitter

The head unit needs to be able to communicate with each of the modules. The reception of the information from each module is necessary for the proper functionality of the system. The received information will be routed through a receiver in the head unit. This receiver will be able to take information from the modules, like the name of the sensor, the sensor number, the data type, and the sensor information[SC1]. The information received can be used to determine if damage from mold, fire, water, or gas has occurred, and where the damages have occurred.

Analytical Method: To ensure that the communication system will properly work, the sensors will be placed based on the manufacture's specifications provided from the transmitters and receivers that will be purchased. When using a communication system that has a transmitter and receiver, it creates its own closed network that does not require any existing internet or WiFi connections. Communication of specific information can be simulated using software such as Matlab. The transmitters and receivers can be programmed to specify what information will be handled between the two.

C. System Modules

1) Head Unit: The head unit will be designed to display active and historical data [SC2]. The head unit will be able to determine the sensor name, number, data type, and raw data [SC7]. This information will be organized and interpreted to know what sensor is sending the data, and the sensor's location, and be able to differentiate from other sensors [SC1]. The head unit will be able to detect if a temperature sensor has a temperature of 176 degrees Fahrenheit or higher and display a warning to the user [SC3]. It will also be able to detect if a water sensor has water present and the total depth of the water [SC4]. The head unit will also be able to determine if the data from the gas sensors are in the specified range according to OSHA standards for a set period of time [SC5]. Finally, the head unit will be able to determine if the data from the mold module is in the specified ranges for humidity and temperature and display a warning for potential mold growth if the conditions are present for a minimum of two days [SC6].

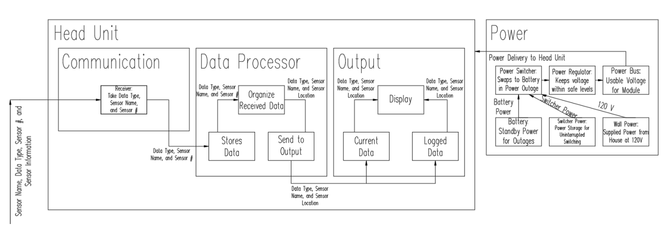

Fig. 4. Block Diagram of Head Unit

2) Mold Module: The mold module will be designed to have humidity and temperature sensors detecting their respective levels in a specified area and send the raw data, in the form of real numbers, back to the head unit [SC15]. These sensors will work together to determine if mold is likely to grow within the specified area. With the data the head unit receives from each sensor, the head unit will trigger a warning for potential mold growth if humidity levels exceed 50% and temperatures range between 55 to 85 degrees Fahrenheit for a minimum of two days [SC6].

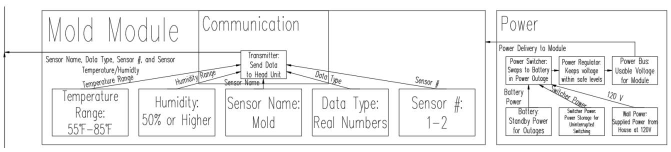

Fig. 5. Block Diagram of Mold Module

3) Gas Module: The gas module will detect three distinct gases – ammonia, carbon oxides, and propane - that tend to overlap in different sections of the house, such as smoke, septic, and natural gases [SC16]. The module is designed to detect these gases in specific areas of the house that are prone to leaks. Once the module detects the gases, built around OSHA standards, the data will be sent to the head unit for diagnosis [SC5].

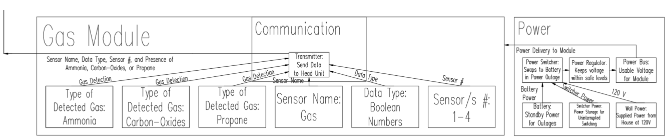

Fig. 6. Block Diagram of Gas Module

4) Fire Module: The fire module will be designed with sensors that will detect the current temperature and send the temperature data in the form of real numbers back to the head unit [SC17]. Once the data is received by the head unit, it will determine if the temperature is 176 degrees Fahrenheit or higher and display a warning message for the user to see [SC3].

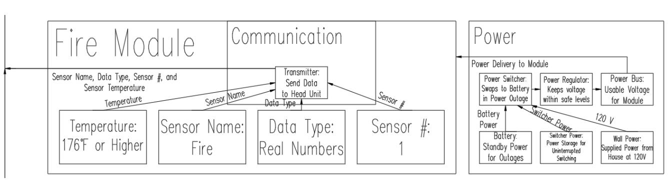

Fig. 7. Block Diagram of Fire Module

5) Water Module: The water module will have a sensor that can detect if water is present and the total depth of water[SC14]. It will then send this information back in the forms of real and Boolean values to the head unit so it can interpret and display the data [SC4].

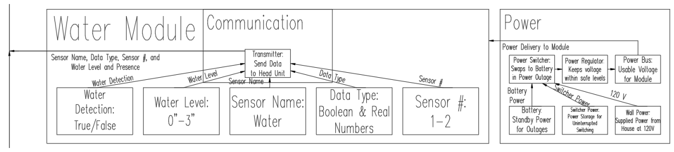

Fig. 8. Block Diagram of Water Module

Analytical Method For Head Unit & Sensor Modules: Sensor data sheets will be analyzed to ensure that each module functions properly and sends relevant information to the head unit. Each sensor module will be programmed to meet the specified constraints given from the parts' data sheets. To ensure that the head unit is capable of receiving data from each sensor module, a Matlab simulation, specifically using Simulink, will be performed to show the process of receiving data and computing calculations inside the head unit to display relevant information to the user. Matlab gives an approach to prove that the process of sending sensor information to another system is feasible.

III. Timeline

The expected timeline for the project is around one year. Figure 9 displays a Gantt chart that shows all of the team's expected completion dates. The team plans to have everything built, utilized, and tested by May of 2024. Each team member will code, create, and test a module and then discuss their findings with the team for future considerations if necessary. The head unit, wireless communication, and power system modules will be completed together as a team. Considering the concepts above, it will be possible for the team to complete this project in the given time.

IV. Conclusion

In conclusion, the Preserve Home Pro project presents a solution to address various home health risks that can cause damage and deplete the value of a home such as gas leaks, fires, floods, and mold growth. The system will consist of multiple sensors and a head unit that will measure, record, and display historical and real-time data, providing homeowners with valuable information to help maintain and protect their homes. Each system module will be integrated into a semi-permanent system with a potential lifespan of up to thirty years. No internet connection will be required as the system will run within a closed network. This system is aimed to potentially help increase property value as well as give homeowners peace of mind that their home will remain in good health. This document serves as a foundational resource for the project, offering solutions aligned with project specifications and constraints and providing a detailed understanding of each subsystem's role, marking a significant step towards revolutionizing home protection and preservation.

References

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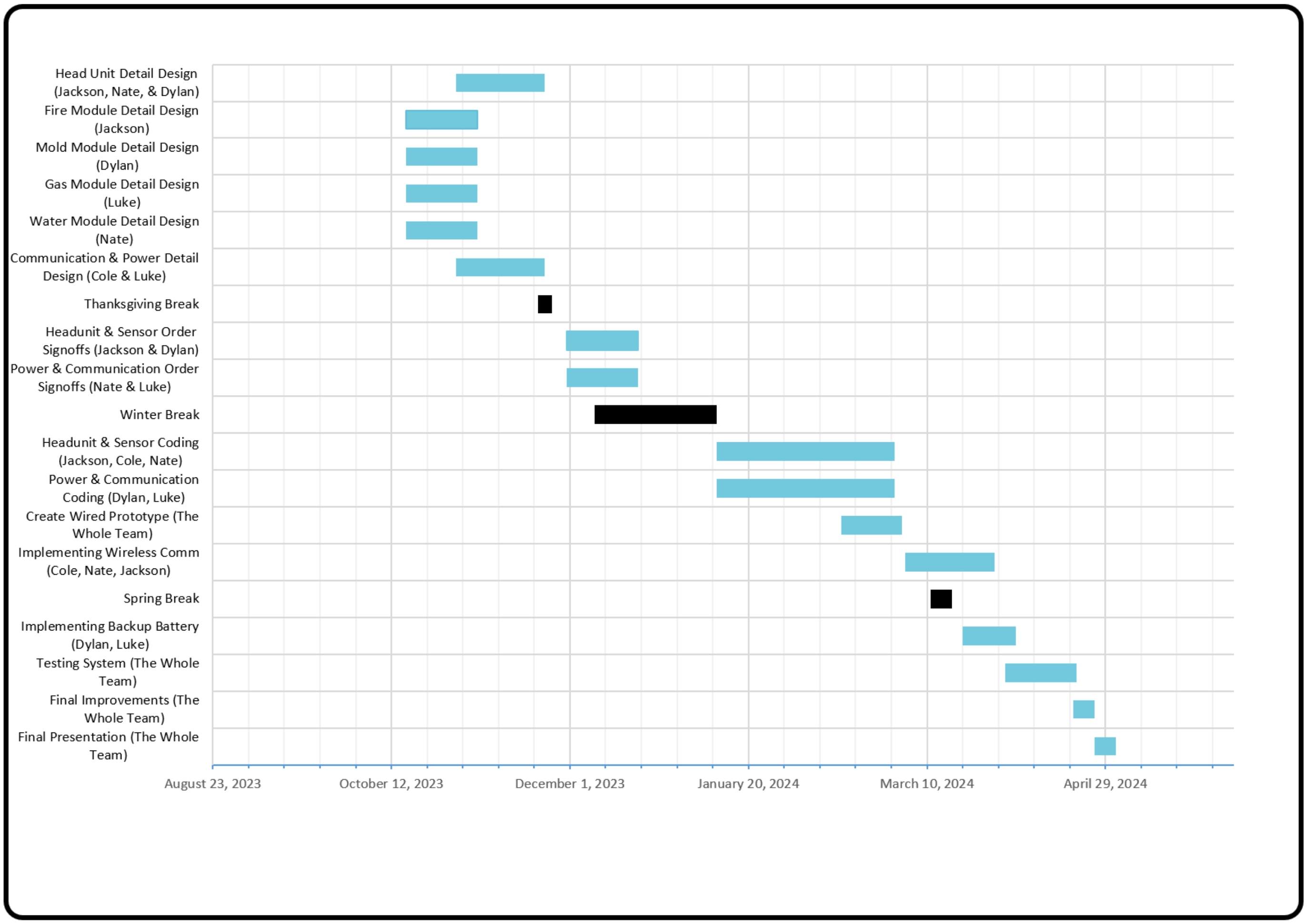

Fig. 9. Expected Timeline

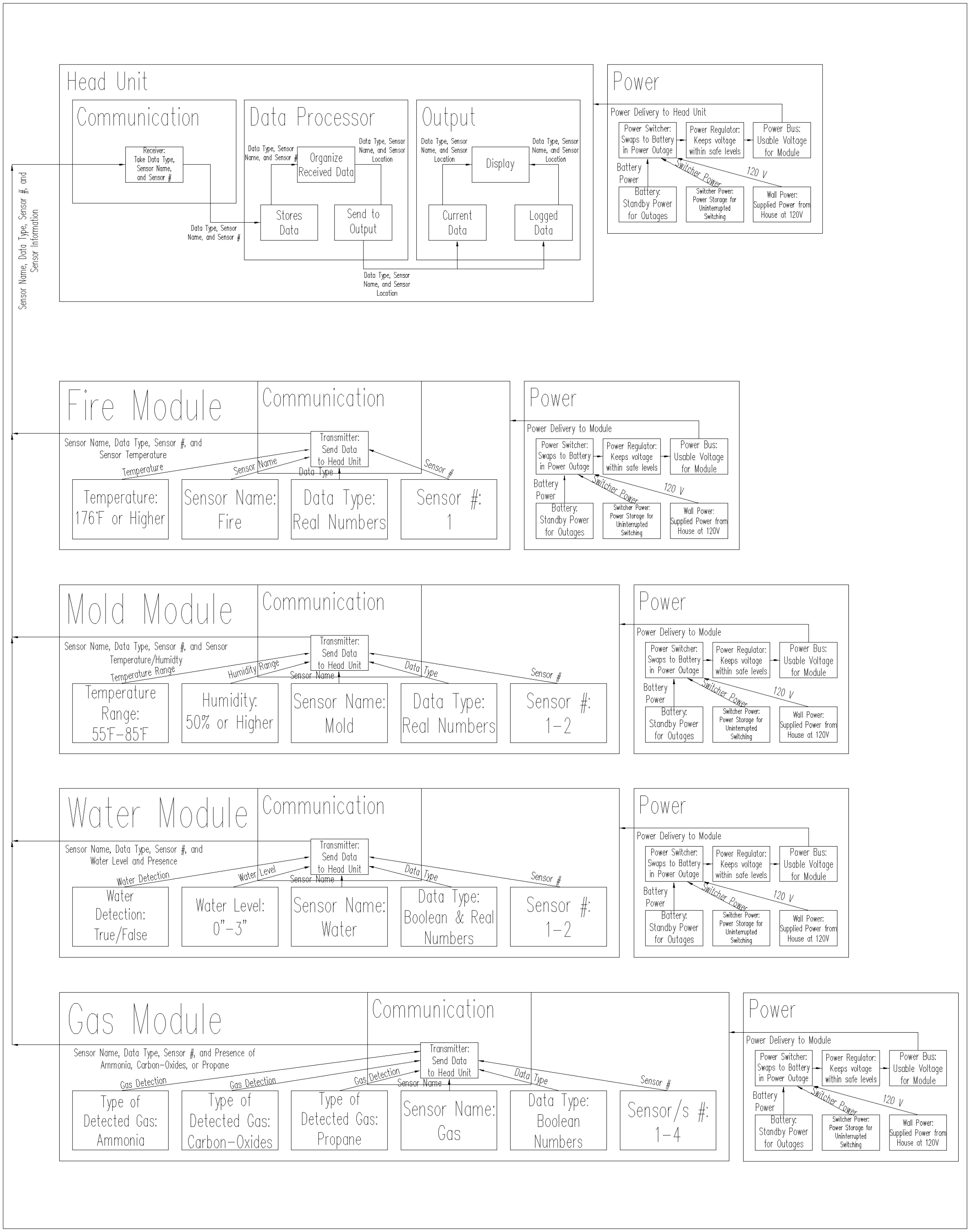

Fig. 10. Detailed Block Diagram