BREATHE: Balanced Responsive Environmental Airflow and Temperature Housing Enhancer

EEL 4914 Senior Design I

Group 40

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1.0 Project Narrative

1.1 Background and Motivation

In today's society, the demand for reliable and efficient home ventilation systems has become paramount. Individuals depend on these reliable home ventilation systems, as they not only establish overall comfort in indoor spaces such as residential, commercial, and industrial spaces, but they also serve to maintain excellent indoor air quality as well as provide the means to regulate temperature. By creating a more effective method of regulating ventilation, BREATHE will be able to sufficiently improve one's health and comfort levels while keeping energy demands low.

Despite advancements in this specific field, there exist some ventilation systems that do not meet the standards that individuals demand in these living spaces. Issues such as inconsistent airflow distribution and poor temperature regulation both contribute to an uncomfortable indoor environment. Moreover, a poor ventilation system can lead to health issues that are problematic to both residential and commercial settings. The circulation of carbon dioxide has been proven to have adverse effects on various environments. For this reason, the importance of proper ventilation not only circumvents the problem of discomfort, but also recognizes the need to monitor the air quality that is being circulated.

Thus, the motivation for this project can be defined by the need to develop an efficient system that directly combats issues that are commonly found in home HVAC systems. This motivation also stems from the team's personal experiences with poor ventilation that results in some rooms with improper heating/cooling systems. Particularly in the tropical state of Florida where rooms can reach upwards of 90 degrees Fahrenheit, many have experienced the discomfort of poorly ventilated rooms. This can become especially unpleasant during the warmer months of the year. The personal struggles in dealing with hot living spaces has reinforced the need to create an efficient system that takes these problems into account.

In developing this project, the team seeks to integrate various electronic and software systems, including environmental sensors and microcontrollers, to intelligently adjust the airflow based on real time environmental data. By taking advantage of these electronic and software systems, air circulation is optimized, thus resulting in a more comfortable living environment.

By addressing both the problems identified in comfortability as well as inefficiencies found in pre-established ventilation systems, the overall aspiration of this project is to bolster the everyday individual's comfortability to their specific needs, facilitate an environment with safe air quality, and contribute to sustainable living. Our motivation leads us to design and implement an efficient and smart ventilation system that not only mitigates the flow of inconsistent and inefficient airflow, but also guarantees an indoor environment that is conducive of a comfortable and healthy living space.

1.2 Previous and Existing products or projects.

1.2.1 Google Home

An existing product on the market that has the ability to adjust temperature via a cell phone application is the Google Home. Google Home has the capability to connect various devices ranging from speakers, doorbell cameras, alarm systems, smoke alarms, Nest thermostats, and beyond. The Nest Thermostat is the device connected through the Google Home app, and this shares the most similarity to BREATHE. With the Nest Thermostat one can view and adjust the temperature of your home's thermostat, toggle from cold to heat settings, select how long the fan should run for, view the humidity percentage of the home, and set a desired temperature schedule per day. It also includes an energy dashboard which displays how much energy is being saved. The device compares the amount of hours of heating and cooling to the previous month, and the daily average of heating and cooling per day. The inspiration we drew from this application as a team was the ability to access temperature readings and manually adjust the temperature output. Our project will be different from this product because we are not modifying the temperature for the entire house, but rather an individual room where our device is placed with a carbon dioxide sensor integrated with our design. BREATHE consists of a manually controlled vent that has the ability to be open or closed in regard to a user's desired room temperature.

1.2.2 The Automated Ventilation Controller

One of the first similar projects to catch our eye was the Automated Ventilation Controller project from another senior design group in 2021. The idea was similar, but instead focused on a warehouse environment where accurate temperature control was a necessity for keeping sensitive components and machinery maintained. We conversely wanted to take a different approach which focused more on the comfort of the average person in a residential space. We also wanted to see if we could further optimize the power consumption to make a more approachable product for your average consumer who wouldn't want to replace a battery every few months. We additionally plan to implement a CO_2 sensor which would alert the user of high concentrations of CO_2 in their living space, something that is not acknowledged often as a health risk. We were also very inspired by their convenient mobile app integration, something that we see many other projects incorporate as well. Though we see this as a stretch goal, we do hope to incorporate a mobile app and autonomous vent control in our project as well.

1.2.3 Ctrl Flow

Another past project we gained inspiration from is a senior design group that altered fan controls to reach desired room environment quality. Their project, the CTRLFlow, is different from ours in that their main controller was operated through a mobile app connected to a remote cloud server. This is how they would change the speeds of the fans and the angle of the louvers to adjust to the temperatures of the corresponding rooms. Our project will pursue similar goals, however, as mentioned prior, we plan on utilizing a CO_2 sensor to optimize the air quality of the room whilst using power-saving techniques to achieve a stronger battery life. As a stretch goal, one technique we would like to implement is a miniature wind turbine to generate electricity, taking advantage of the AC airflow.

1.3 Project Goals

The overarching goal of BREATHE is to design and develop a vent system that will open or close in order to adjust the airflow in a room while monitoring basic environmental conditions such as temperature and carbon dioxide. Using real-time data that is provided by the respective sensors, BREATHE should aim to facilitate a comfortable living space. The fundamental basis of this project's objectives can be simplified to a set of basic, and stretch goals described below.

Basic Goals

1. The vent can be opened or closed fully from user input.
2. Autonomous control of the vent will be based on user-specified temperature parameters.
3. The temperature of the room in which the vent is located will be regulated based on user input.
4. The sensor will accurately sense the carbon dioxide level of the room it is located in and alert the user if carbon dioxide concentration exceeds recommended levels.
5. The power system will ensure a reliable delivery of power to each necessary component.
6. The device can fit inside the small space of a basic AC vent.
7. A touchscreen LCD Screen will be used to display sensor values and control the device
8. BREATHE will be Bluetooth compatible.

Stretch Goals

1. The user can open the vent to a desired angle.
2. BREATHE will incorporate a fan behind the vent to be used as a power generation feature similar to a wind turbine in order to increase battery life of the vent subsystem.
3. BREATHE will incorporate a fan behind the vent to be used in the event that Carbon dioxide levels are high and increase airflow into the room to dissipate excess Carbon dioxide
4. A mobile application will be used as a secondary way to control BREATHE.

1.4 Project Objectives

In essence, BREATHEs objective is to provide a user with an efficient ventilation system that adjusts airflow that is dictated by environmental conditions, ensuring the facilitation of a comfortable living space. With respect to comfortability, BREATHE will be designed to tailor the airflow of the vent in response to any variations found in room temperature. For example, the colder the room temperature, the more restricted the air flow will be and the hotter the room temperature, the less restricted the air will be. In essence, BREATHE will have the capability to attenuate airflow based on sensed room temperatures, thereby facilitating comfortability in a living environment.

BREATHE will provide users with the capability to provide full manual control on the airflow based on their input. A vent interaction sub-system will allow the vent to be adjusted between a fully open and fully closed position through the use of a DC motor, which will be controlled by an MCU. The user will be able to implement these adjustments via a control unit which houses the LCD unit and the sensors. Alternatively, the user can specify a desired temperature value, which enables an autonomous mode that will fluctuate the vent's state to change based on the current sensor reading of the room's temperature.

BREATHE will have a control sub-system with an LCD unit that takes in user input in conjunction with sensors to provide accurate readings of temperature and CO_2 levels. In order to achieve reliable and accurate readings, an appropriate temperature and CO_2 sensor will be selected. Calibration methods, such as multi-point calibration and span calibration, will be implemented to ensure accuracy over its operating range. These sensors will be connected to a secondary MCU, which will be responsible for aggregating and interpreting the data gathered from both the temperature and CO_2 sensor.

Furthermore, BREATHE will need a power system that is capable of delivering power to all subsystems including the temperature sensor, CO_2 sensor, DC motor, LCD screen, and both MCUs. Implementing this system will bring challenges, such as finding a suitable battery that will provide adequate power to each component and limiting the battery usage of each subsystem to reduce the inconvenient task of replacing the battery frequently. This problem necessitates finding a bluetooth compatible MCU and sensor with relatively low power consumption that will still satisfy our technical requirements. Modes such as Sleep Mode and Power Down Mode can be integrated in tandem with a reliable power supply section to optimize energy usage.

Next, BREATHE will have an LCD unit that is used to control the vent system and display sensor values. The utilization of a touchscreen LCD along with an intuitive interface will create a user-friendly and easy-to-use system. The LCD unit will be programmed to display different warnings if necessary, with the help of visual and audio cues. One of the display warnings will be for low battery reading of the vent and LCD units, which will consist of an intermittent beep and a warning message on the LCD screen. The other display warning will be for a high CO_2 sensor reading. If the CO_2 sensor reads a theoretical value of 4000 ppm, the LCD unit will sound an alarm and present a warning message on the screen. A dedicated MCU will be needed to power the LCD screen and manage its associated functions.

Lastly, BREATHE will be Bluetooth compatible, allowing communication between both MCUs involved in the overall system. Intuitively, the MCUs chosen will need to have Bluetooth integrated within them. Bluetooth connectivity will be tested in order to confirm an established and reliable communication method between MCUs over a specified range. Software will be developed for Bluetooth communication protocol to ensure scalability and communication with both the sensors and DC motors to the main unit from different rooms.

2.0 Specifications

Specification	Description	Quantitative Measure
Manual Vent Control	The system should be capable of manual operation that fully opens or closes the vent through user input	Vent can be in 1 of 2 positions, *open or closed*.
Autonomous Vent Control	The system should be able to	If the temperature variation (in

	autonomously adjust the louver position according to the room's temperature and the user's desired temperature threshold.	*°F)* is ≥ *5%*, the vent should open or close depending on if the variation is above or below the desired temperature set by the user.
Sensor Accuracy	Sensors should maintain high accuracy within a specific range	Temperature reading should be accurate to *±1°F* and CO_2 reading should be accurate to *±50 ppm*
Sensor Operating Range	Each sensor should have a sufficiently wide defined operating range to accommodate for extreme conditions.	Temperature sensor operation range should be from *-40* to *176 °F,* whereas the CO_2 sensor operation range should be from *0 ppm to 5000 ppm*
Power System Operation Duration	Units should be able to operate for a certain length of time before a battery replacement.	Minimum duration of *6 months* before needing replacement
Bluetooth Range	Bluetooth communication should work within a specified range	Bluetooth communication should work up to a *10-meter range*
Form Factor	The overall system's physical dimensions should fit within the average residential vent cover design.	*6"x1.5"x1cm*
Audio Alarm System	An audible alarm should be triggered when CO_2 levels exceed a certain threshold. A separate alarm will trigger when the battery is low.	Alarm sounds when CO2 *exceeds 4500 ppm.* When the battery of either the LCD unit or vent control unit is below *10%* capacity it will sound intermittently at a lower pitch and volume.
Vent Actuation Time	The vent should fully open or close within a defined time limit.	Vent will be able to fully open or close within *5 seconds*

Figure 4. Specification Table

3.0 Block Diagrams

3.1 Hardware

The system is split into two main sections: the vent interaction subsystem, and the control unit which houses the LCD unit, and sensors. The diagram shows the communication between each of the components, as well as the main interactions between each sub-system. The vent interaction sub-system focuses on delivering proper airflow to the environment by utilizing a motor to adjust louver positions. The control unit focuses on taking input from the sensors and the LCD unit is responsible for sending the control signals to the vent interaction sub-system.The LCD unit will then display information such as temperature and CO2 levels, allowing data to be monitored. It will also trigger an alarm if a hazardous situation occurs. The Hardware Diagram is shown below.

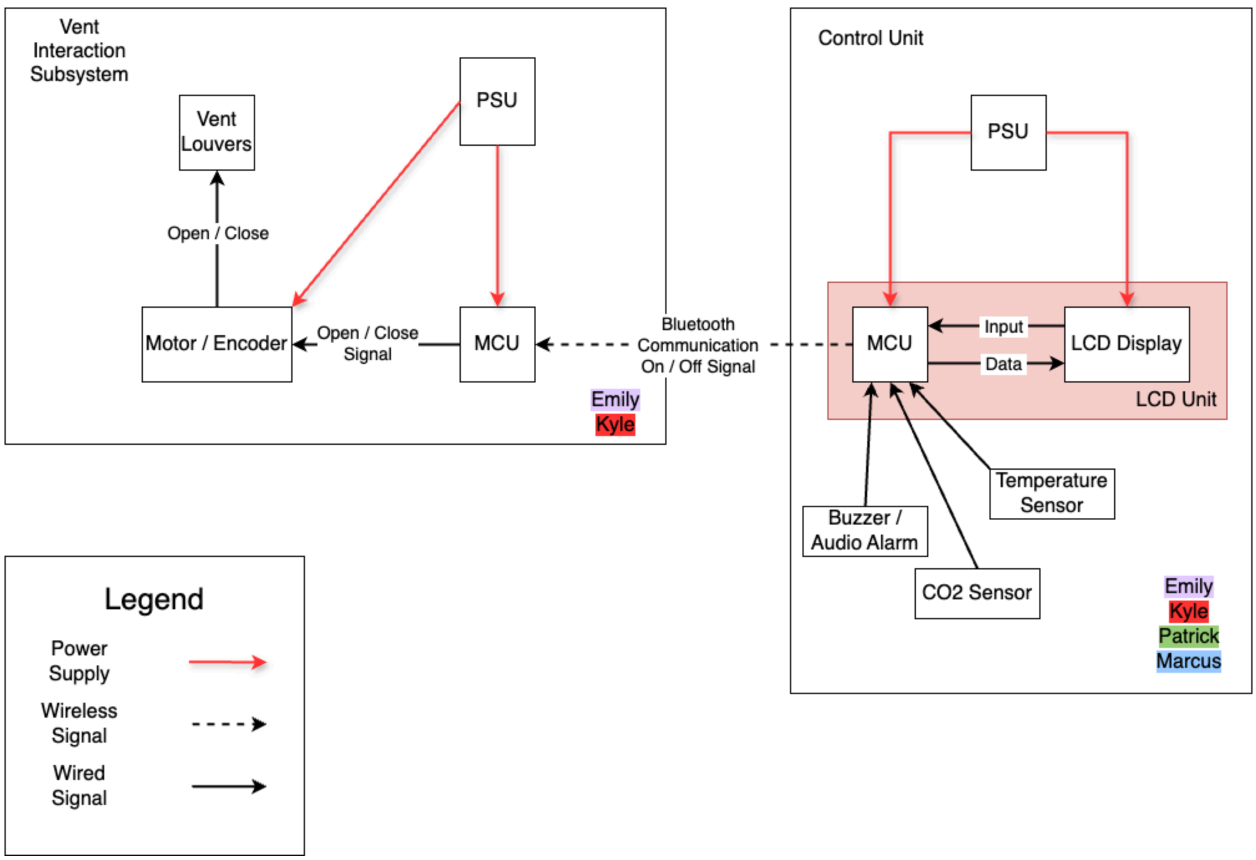

Figure 1. Hardware Diagram

3.2 Software

The software use-case flow chart below demonstrates the functional interactions between each of the three subsystems, as well as the work distributed between group members.

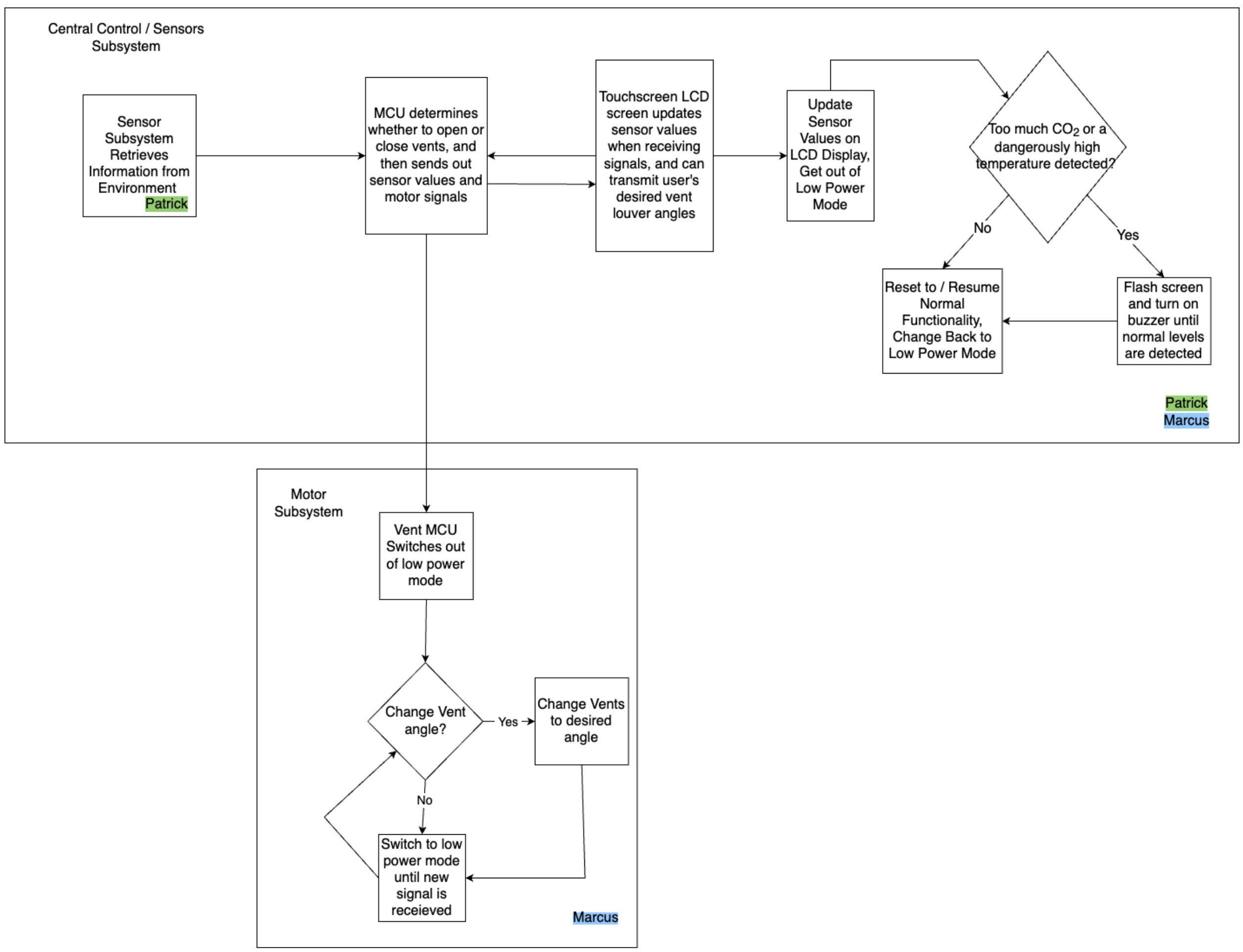

Figure 2: Software Flowchart

4.0 House of Quality

Showcasing the polarities as well as correlations between the functional requirements and the customer requirements the House of Quality diagram is shown below.

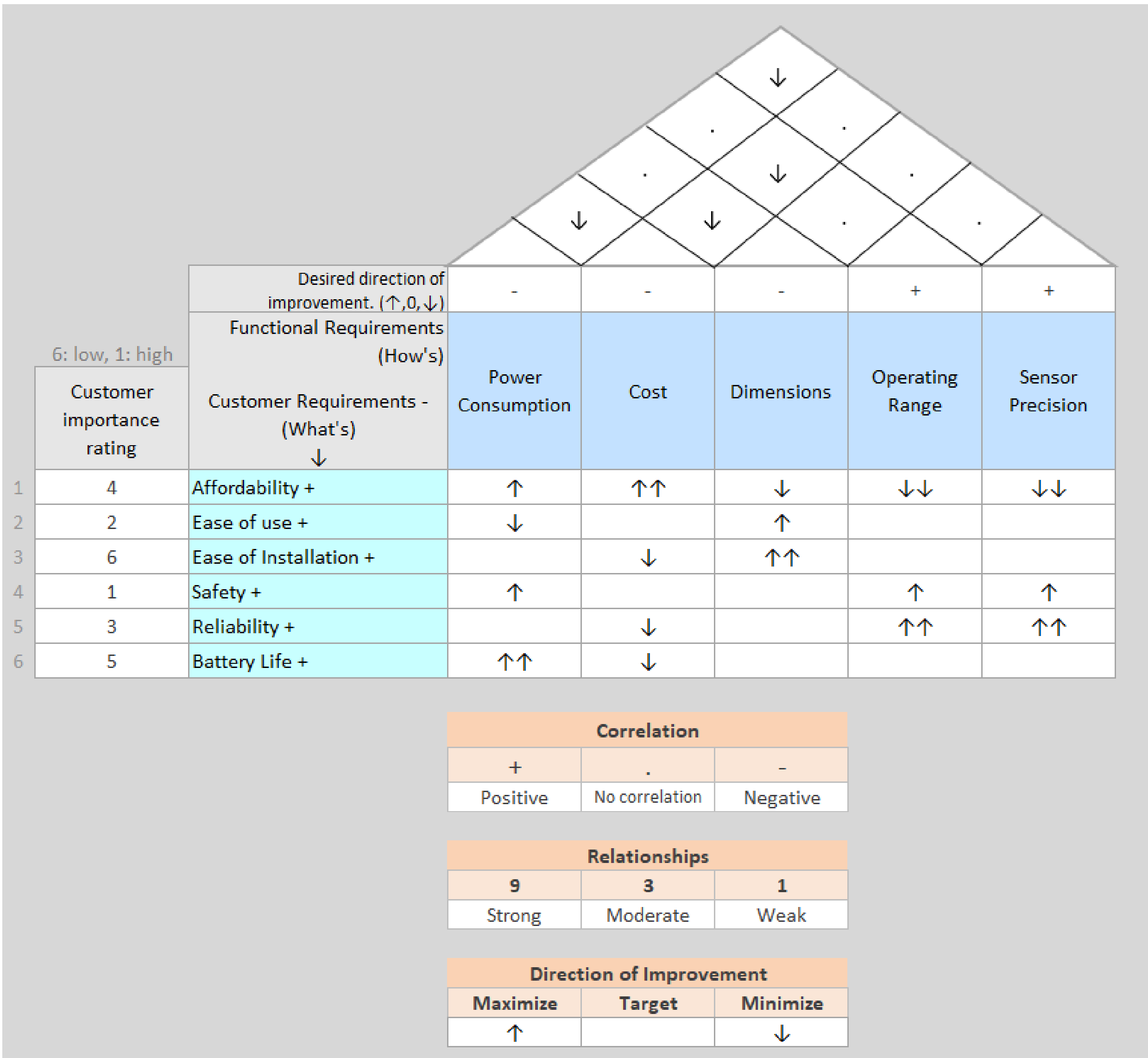

Figure 3. House of Quality diagram

5.0 Budget

Item Description	Quantity	Estimated Price	Overall Cost
PCB Boards	2	$35	$70
MCU’s	2	$25	$125
DC Motor	1	$15	$15
Temperature Sensor	1	$10	$10
CO_2 Sensor	1	$30	$30
Batteries	2	$40	$80
Sample Vent	1	$20	$20
Panel Enclosure	1	$30	$30
Touchscreen LCD	1	$0	$0
Passive Speaker	1	$2	$2
	Total Cost		$382

Figure 5. Budget Table

For the budget, the team opted to account for the absolute worst case scenario in terms of cost for each of the items needed to fulfill our project’s design. The two MCU’s we plan on using will likely cost less than $25, but we determined the most costly MCU to use for our sensors would be around that price if we use an existing integrated board. The same methodology is applied to the two batteries we plan on using. Fortunately, we already own a resistive touch TFT LCD screen so this cost will not be factored into the budget. We have researched many different options which might fit within our project goals based on power consumption and safety. Depending on what works best and fits within our constraints, we adjusted the budget to allow some flexibility. It is very likely the total cost will not reach this estimate, but this should be a good estimate based on the direction we plan to take our project in. Thankfully, as long as no parts are damaged, this budget should be fairly accurate when accounting for possible PCB fabrication issues. This project is sponsored, but despite that we are aiming for this project to be relatively low cost in its most basic form.

6.0 Project Milestones

Task	Task Description	Start Date	Anticipated End Date
Group Formation	Form a group before the second lecture *Group Formation*	8/20/2024	8/22/2024
Project Idea Creation	Formulate a project idea	8/22/2024	8/30/2024
Divide and Conquer Document	Finish at least 10 pages of the D/C document	8/30/2024	9/6/2024
Divide and Conquer Meeting with Professor	Discuss divide and conquer document and take note of criticism and plan to make changes	9/10/2024	9/10/2024
Divide and Conquer Revisions	Discuss criticisms given and make religions to the Divide and Conquer Document	9/10/2024	9/27/2024
60 Page Report Draft	Finish our group's 60 page report draft	9/28/2024	10/25/2024
60 Page Report Revision	Discuss criticisms given and make revisions to the 60 page report	10/26/2024	11/8/2024
Final Report and Mini Demo Video	Complete the Final Report and Mini Demo Video for SD1	11/9/2024	11/26/2024

Figure 6. Senior Design I Milestones

Task	Task Description	Start Date	Anticipated End Date
PCB Testing	Start PCB testing and ensure they all function	TBD	TBD

	as desired		
System Integration and Testing, incorporate stretch goals if possible	Start integrating all subsystems together and begin testing their functionality. Begin implementing stretch goals if realistic and possible. Need some time to identify and correct errors on both the software and hardware side.	TBD	TBD
Finalize project prototype	Finalize implemented all subsystems together into one, cohesive project.	TBD	TBD
Practice Project Demo	Begin practicing a simulated project demonstration to make sure everything works as anticipated	TBD	TBD
Possibly implement optimizations (if necessary and or possible)	If a system can be improved, begin implementing new optimizations to BREATHE.	TBD	TBD
Finalize any documents	Finalize any documents needed	TBD	TBD
Group Practices Final Presentation	Practice Final presentation as a group	TBD	TBD
Final Presentation	Present final project to SD committee.	TBD	TBD

Figure 7. Senior Design II Milestones

Appendix A. References

[1] Google, "Understand Google Smart Home Compatibility," *Google Home*, Sept. 6, 2024. [Online]. Available: https://home.google.com/what-is-google-home/. [Accessed: Sept. 6, 2024].

[2] J. Mansy *et al.*, "CtrlFlow," *CtrlFlow - Group 17*, 2021. [Online]. Available: https://www.ece.ucf.edu/seniordesign/fa2020sp2021/g17/#team. [Accessed: Sept. 6, 2024].

[3] W. Dominguez *et al.*, *The Automated Ventilation Controller*, 2021. [Online]. Available: https://www.ece.ucf.edu/seniordesign/su2021fa2021/g15/. [Accessed: Sept. 6, 2024].