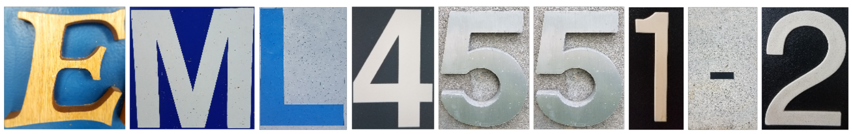
9/29/2023



Team 506: CIA Gas Detection

Shawn Butler; Benjamin Labiner, Alex McIver, Jane Nordhagen, Michaela Porcelli

FAMU-FSU College of Engineering 2525 Pottsdamer St. Tallahassee, FL. 32310

Abstract

Keywords: CIA, Gasses, Detection

Disclaimer

Acknowledgement

Team 506 would like to thank the CIA for sponsoring this project and for assisting us in developing the most effective product possible.

We would also like to thank Dr. McConomy for teaching us the skills and knowledge to follow the engineering design process.

Table of Contents

Abstract ii
Disclaimer iii
Acknowledgement iv
Table of Contents v
List of Tables vii
List of Figures viii
Notation ix
Chapter One: EML 4551C 2
1.1 Project Scope 2
1.1.1 Project Description 2
1.2 Customer Needs 5
1.3 Functional Decomposition 8
1.4 Target Summary 15
1.5 Concept Generation 18
Concept 1. .... **Error! Bookmark not defined.**
Concept 2. .... **Error! Bookmark not defined.**
Concept 3. .... **Error! Bookmark not defined.**
Concept 4. .... **Error! Bookmark not defined.**

Deleted: 1
Deleted: 2
Deleted: 3
Deleted: 4
Deleted: 5
Deleted: 6
Deleted: 7
Deleted: 8
Deleted: 9
Deleted: 9
Deleted: 11
Deleted: 14
Deleted: 19
Deleted: 19
Deleted: 20
Deleted: 20
Deleted: 20
Deleted: 20

Concept n+1. Error! Bookmark not defined.
1.6 Concept Selection 24
1.8 Spring Project Plan 32
Chapter Two: EML 4552C 32
2.1 Spring Plan 32
Project Plan. 32
Build Plan. 32
Appendices 33
Appendix A: Code of Conduct 34
Appendix B: Functional Decomposition 37
Appendix C: Target Catalog 38
Appendix D: Work Break Down Structure 41
References 51

Deleted: 20
Deleted: 20
Deleted: 20
Deleted: 20
Deleted: 20
Deleted: 20
Deleted: 21
Deleted: 22
Deleted: 22
Deleted: 25
Deleted: 26
Deleted: 27
Deleted: 30

List of Tables

Table 1 – Customer Needs ….. 12

Table 2 - Cross-Functional Relationship Matrix 18

Table 3 – Critical Functions and Defined Targets 21

List of Figures

Figure 1 – Main Functions Hierarchy Chart ….. 15

Figure 2 – Team 506 Main Functions Hierarchy Chart 15

Notation

CIA	Central Intelligence Agency
PPM	Parts per Million
LEL	Lower Explosive Limit
UEL	Upper Explosive Limit

Chapter One: EML 4551C

1.1 Project Scope

1.1.1 Project Description

The objective of this project is to design, develop, and deploy a wearable gas sensor system tailored for CIA search and rescue operations the specific scenario we will focus on is a building collapse This system will equip CIA teams with a reliable and portable tool for detecting and monitoring hazardous gases in disaster-stricken areas, ultimately enhancing the safety and effectiveness of missions. Our project offers seamless integration into Team 505's wearable safety system, providing the flexibility to either detach from the main system or function independently as a standalone unit.

Deleted: .
Deleted: ,.
Deleted: ,
Deleted:
Deleted: specifically a.

1.1.2 Key Goals

Deleted: ¶
Deleted: ¶

The objective of this project is to create a wearable gas sensor for search and rescue operations, with a focus on the CIA principles: Confidentiality, Integrity, Intergration and Availability, to ensure the highest level of data security and reliability. Confidentiality goals include encrypting sensitive gas concentration data and controlling access to authorized personnel. For integrity, the sensor must validate data accuracy and maintain tamper-proof data logs. For our Intergration goals we want to be able to have the sensor read and display information on Team 505 search and rescue device. Availability goals require redundancy and remote monitoring to ensure uninterrupted functionality during critical missions. Comprehensive cybersecurity and physical security measures are essential to safeguard against threats. Usability goals encompass user training and an intuitive interface, while compliance ensures adherence to relevant regulations and ethical considerations, thus ensuring the effectiveness of the gas sensor in search and rescue efforts while upholding data integrity and privacy. The wearable will be modular to allow for first responders to adjust where on the body they wear the box/sensors.

Deleted:

1.1.3 Markets

Primary Market

The primary market for wearable gas sensors in search and rescue operations with a focus on the CIA (Confidentiality, Integrity, and Availability) principles is the public sector and government agencies involved in emergency response and national security. These organizations include fire departments, law enforcement agencies, and military units specializing in disaster response and chemical threat detection. These users prioritize the reliability, security, and confidentiality of sensor data to ensure effective decision-making during critical missions.

Secondary Markets

Secondary markets include private sector entities engaged in activities such as industrial safety, hazardous material handling, and environmental monitoring. Companies in sectors like oil and gas, chemical manufacturing, and construction can benefit from wearable gas sensors for employee safety and environmental compliance. For example, the MagLab would be interested in it for maintenance repairs on pipe leaks. Additionally, Universities like Florida State and FAMU may be interested in it for their science Labatories. While they also require reliable and secure sensor solutions, their primary focus may not be on the stringent security measures demanded by government agencies, making them a secondary market segment.

1.1.4 Assumptions

Our assumptions have been derived from the conversations we have had with our sponsor about their goals and expectations for this project.

Our first assumption for this project is that the scenario(s) being designed for this project will be completely representative of the use case for this project. Team 506 (with team 505) is working to design appropriate scenarios for which a wearable gas sensor could be used by the CIA. While the designed product may be helpful in other situations, our design will be tailored to the selected scenario(s).

We are also assuming that we will only be attempting to detect known gases. The detection method that will be used is yet to be determined, but we will not be responsible for quantifying characteristics of novel gases. If characteristics of unknown gases can be determined, this will be desirable, but it will not be a main goal of the project.

We assume there is no expectation of concealment for this project unless our sponsors state that it would be beneficial in a selected scenario. The CIA is known for spy-craft, but this project will primarily be focused on search and rescue operations, where concealment of safety equipment is not typically desirable.

Deleted: We are assuming that there is no expectation of concealment for this project, unless our sponsors state that it would be beneficial in a selected scenario.

We are as well assuming that Team 505 and Team 506 project/device should be integrable together and work together as one device.

1.1.5 Stakeholders

Central Intelligence Agency (CIA), Senior design professor Dr. Shayne McConomy, and the FAMU-FSU College of Engineering. Dr. Shayne McConomy is the advisor for this project, and the FAMU-FSU College of Engineering is represented, so they are interested in this product.

1.2 Customer Needs

1.2.1 Investigating Needs

The CIA has partnered with the FAMU-FSU College of Engineering to develop a wearable device with the ability to detect harmful gases in the environment. The CIA placed Franklin Roberts, designated team advisor and liaison, to be our main point of contact regarding topics related to the wearable gas sensor. To understand the needs and wants of the CIA for the wearable gas sensor project, Team 506 conducted a customer interview via Google Meets on October 6th at 2pm EST with the CIA team. The questions were open-ended and made to avoid scope creep. The responses to the set of questions, along with the interpreted needs are displayed in Table 1.

The feedback obtained from the questions has assisted the team in refining the focus of this project, highlighting the crucial areas for attention. Our inquiries primarily centered on the primary functions of the gas sensor, any environmental limitations, and the size and weight of the device. Based on the CIA's answers, the team made an interpretation of the sponsors response for each question. These interpretations were formulated to describe the underlying requirements needed to transition into the next phases of the project and understand device requirements and constraints.

Table 1: Customer Needs Breakdown

Question	Sponsor Response	Interpretation
1. Is the purpose for tracking or for warning the wearer?	“The main purpose is to warn the user. Tracking the sensor is not necessary.”	User notification is main objective
2. What are the expected mission durations, and how does this impact battery life requirements?	“As long as possible without using a heavy battery.”	Long battery life without an unwieldy battery weight
3. Are there any weight or shape constraints?	“Yes, keep it lightweight.”	Have a lightweight (< 40 lb.) device
4. Are there any specific reliability or durability standards to keep in mind?	“You do not need to follow any standards or regulations because that cost too much money and is too complex.”	There is no explicit standard of reliability/durability
5. What training and support resources are required for CIA operatives to effectively use and maintain the gas sensor?	“No training is needed.” Create just a basic manual for the components	Make the system intuitive and easy to use. Have basic manual just in case
6. Are there considerations for maintaining operational discretion and keeping the gas sensor covert or discreet when needed?	“The device can be hidden or on the outerwear of the user.”	Device can be visible or covered.

7. Does the device need to be heat/Temperature Humidity resistant?	"Withstand realistic heat/humidity temperatures."	Realistic temperatures range from 20°F - 120°F
8. How do you want the data transmitted? (In a database etc.)	"Transmitting the data is not a hard requirement."	Data from can be transmitted however the team pleases as long as hard requirements are completed first.

1.2.2 Explanation of Results

From the interpreted customer needs, the most important needs were for the device to be wearable, be able to detect gas, and to prioritize shelf life and power. The design primarily focusing on warning the user of harmful gases rather than back hauling the data to a central location. The customer is concerned about the size and the weight of the device in order to keep the scenario realistic while considering the relative weight of the battery.

With respect to high safety standards and preventing hazardous incidents the team will not use toxic gases and be tested in a safe environment. The final concept is open for interpretion between Team 505 and Team 506. The assumption that the wearable gas sensor will be used in a building collaspe search and rescue scenario was agreed upon with the CIA and the two Senior Design teams.

Ultimately, throughout Senior Design, the CIA wants to updated with designs, and prototypes of the device. By the end of Senior Design, they most desire to have a functional prototype that can detect gas, be wearable, and have a good shelf life.

1.3 Functional Decomposition

1.3.1 Introduction

Functional decomposition is a process of analysis that breaks a complex system to into smaller and simpler functions. The purpose of functional decomposition is to organize the functions of a project in a hierarchy, detailing what the project has to do. It begins by breaking down the problem statement and gathering information on what the customer needs. This process assissts in the steps that are needed to be completed in order to achieve the project goal and produce the final product. The following functional decomposition was gathered collectly with team 505, 506 and our sponsors. Additionally, the team utlizied past Senior Design projects for reference and used engineering design methods to gather the following data.

1.3.2 Data Generation and Hierarchy Introduction

Team 506 conducted an analysis of the project description, assumptions, key goals, and customer needs to determine the major and minor functions of the desired gas sensor system. The major functions were classified into systems based on important functional relationships. The gas sensor was broken down into 2 systems proceeding into 2 subsystems. Figure 1 displays a visual representation of our functional decomposition. The figure follows a tree hierarchy with the 2 main systems: gas sensing and the wearable component.

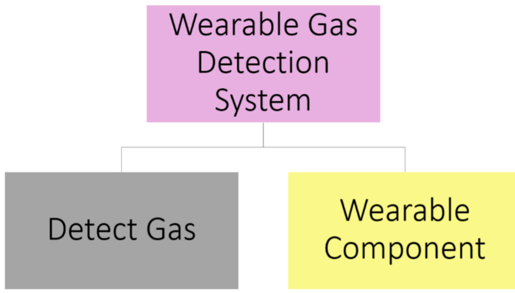


Figure 1: Team 506 Main Functions Hierarchy Chart

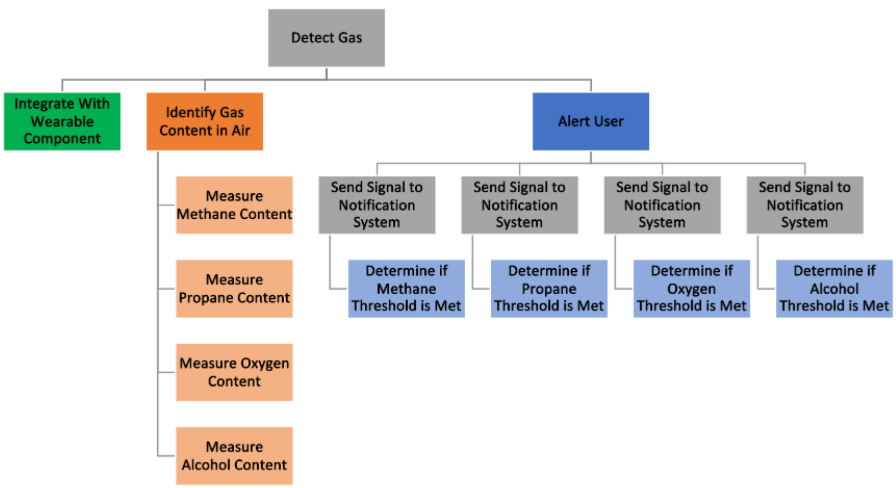


Figure 2: Detect Gas Hierarchy Chart

1.3.3 Hierarchy Chart Explanation

Figures 1 and 2 display the functional decomposition in the form of a hierarchy chart. The functions identified were classified into 3 different major subsystems: to integrate with wearable component, identify gas content in air, and alert user. This data was generated based off of our meeting with the CIA regarding the main functional needs this device needs to do.

The first branch is to intregrate with wearable component. Although having no subsytems below it, this is more towards our sister team 505 since our device will collabrate with their project.

The second branch is to identify gas in air. Simply stating that our device should be able to intake gas constantly and read out how much gas is being surrounded. The few gasses that the sensor will be reading is the methane content, propane content, oxygen content, and alcohol content.

The third branch is to alert the user to determine if each gas threshold is met to optimal standards. In some circumstances, the user will be around these gasses everywhere. So the threshold of gas until it becomes harmful or even deadly.

1.3.4 Connection to Systems

Each of the major subsystems, besides integrating with Team 505, have subsystems within them. Idenentifying the gas content of the air and alerting the user have been broken down to their most basic functions to establish the data-flow order.

Integration With Wearable Component

This project is broken into two teams, Team 506 is designing a gas sensor and alerting system, Team 505 is designing a wearable system that the gas sensor will integrate with. The ability to integrate with Team 505's system is a major function of this sensor, there are no sub-functions of this major function currently. As mentioned, this is priority number 2.

Identify Gas Content of the Air

A major function of this system is detecting and recognizing gasses present in the environment. The identification of each gas is considered to be its own function to emphasize the importance of each gas. Depending on the detection method used, different gasses will need to be tested with an independent sensing device. The gasses currently listed have been determined by analyzing which gasses are most likely to be present in our given scenario, as well as which gasses will present a clear and present danger. The device will detect the value of each gases' concentration or presence to be logged and communicated to the user. Since this is the teams main objective, this is priority number 1.

Alert User

Once gasses have been detected in the air and their concentration determined, the user must be made aware of the concentration of the air around them. The method by which the user will be notified is still to be determined and will depend on decisions made by Team 505 through the next iterations of the design process. The major function of alerting the user has two sub-systems below it. The lowest level function in alerting the user is comparing the measured gas concentrations to set thresholds where the gasses will become deadly. If these thresholds are met, a signal will be sent to the notification interface and the user will be made aware. Potential solutions to user notification will include constant updating of air quality, but thresholds will still be in place for emergency alerts to the user. This is priority number 3.

1.3.5 Cross Reference Table

The functional dcomposition cross reference chart, Table 2, demostrates how the functional systems of the device relate to one another. The columns are the 3 main systems and the rows are the 8 sub-systems. An 'X' denotes when a sub-system function will be directly affected by one or more of the 3 main systems.

Table 2: Cross-Functional Relationship Matrix

Sub-Systems	Integration	Identify Gas Content	Alert User	Total
Measure Methane		**X**		**1**
Measure Propane		**X**		**1**
Measure Oxygen		**X**		**1**
Measure Alcohol		**X**		**1**
Determine if Methane Threshold is Met			**X**	**1**
Determine if Propane Threshold is Met			**X**	**1**
Determine if Oxygen Threshold is Met			**X**	**1**
Determine if Alcohol Threshold is Met			**X**	**1**
Send Signal to Notification System (Methane)	**X**		**X**	**2**

Send Signal to Notification System (Propane)	**X**		**X**	**2**
Send Signal to Notification System (Oxygen)	**X**		**X**	**2**
Send Signal to Notification System (Alcohol)	**X**		**X**	**2**
Total	**4**	**4**	**8**	**16**

1.3.6 Smart Integration

When this gas sensor is implemented, the different subsystems will need to communicate with eachother for the total system to be effective. The main subsystems that will need to work in conjunction are the gas measurements and the checking of thresholds. When the gas measurements are taken, these values must be interpreted by a different subsystem to effectively notify the user. The interpreted values must also interact with the subsytem responsible for notifying the user at appropriate intervals. Communication methods between sub-systems is yet to determined, but will likely incorporate wired serial communication, bluetooth/RF communication, or an analog method.

1.3.7 Actions and Outcomes

The Wearable Gas Sensor serves as an essential tool for safeguarding lives and ensuring successful outcomes during search and rescue missions. This type of device actively detects and monitors hazardous gases in real-time. Our device will provide first responders with crucial data to make informed decisions and protect their safety by issuing immediate alerts. Wearable gas sensors enhance the efficiency of rescue efforts and minimize exposure to toxic gases. This will ultimately contribute to a safer and more effective search and rescue operation.

The main physical action to be performed is to successfully display the accurate percentage of gas concentration and relate it to its lower explosive limit (LEL) and the upper explosive limit (UEL). Every gas has a different LEL and UEL; therefore, the team must find a way to integrate each of the 4 gases LEL's and UEL's. Gas concentrations vary from location to location; dense gases will be lower to ground and visa versa. Thus, when the user goes into a search and rescue mission with our device it is important to have a large margin or error in our percent readings in order to keep the user safe.

Another physical action to be performed is to successfully communicate with the wearble component. Depending on the following design steps, this integration between the wearable component and the gas sensor will become more clear. For example, if the final product is strictly mechanical device, the device could communicate with the wearable component through valves. On the other hand, if the final product is more eletrical and software based, the communication can happen via bluetooth or wires.

1.3.8 Function Resolution

The functional resolution of the gas sensor is tailored for search and rescue missions with a set of capabilities, including the detection of a wide range of hazardous gases, adjustable sensitivity levels, real-time monitoring, compact and wearable design with conditions to withstand extreme conditions, audible and visual alarm mechanisms for immediate notification, integration with other equipment, efficient battery management, and adherence to safety protocols. This comprehensive functionality ensures that the sensor provides critical, life-saving information in real-time while being seamlessly integrated into the search and rescue operational environment, ultimately enhancing the safety and effectiveness of missions in disaster-stricken areas.

1.4 Targets and Metrics

After identifying the functions for our design project, each function must be assigned a target and metric. Targets are specific values used to quantify qualities of a design. Metrics are the tools used to validate those targets. Critical functions were identified from the product's functional decomposition hierarchy chart and cross reference table. Team 506 Engineers based the targets and metrics on the project scope, customer needs and the team's interpretation of a feasible target. A complete catalog of the targets and metrics for all functions can be seen in Appendix C: Target Catalog. The full Target Catalog includes the targets and metrics of both Team 505 and Team 506 to help show the overall project targets and metrics. Of our targets, the designated critical targets and metrics are essential for our project's success.

1.4.1 Critical Targets/Metrics

Table 3 shows the critical functions of the product and their assigned targets.

Table 3: Critical Functions and Defined Targets

System	Function	Target	Metric

Inputs	Identifies combustible gases	Focus on 3 combustible gases	Voltage
Inputs	Identifies volatile organic compounds (VOCs)	Focus on 1 VOC: paint thinners	Voltage
Additional	Measures gas concentrations	Read at least 300 parts per million (PPM)	PPM or volume %
Outputs	Sends signal to notification system	±10%	Voltage

1.4.2 Targets/Metrics Derivation

Identifies combustible gases

This system will focus on three (3) main combustible gases. This is due to the situation of a building collapse and only being able to accessible gases to test. Propane, methane, and carbon monoxide are the main combustible gases that will be focused on. Other gases will still be detected, such as oxygen for oxygen deprivation. The sensor should be able to detect these gases if they are mixed as well. This target can be measured through the sensor and read in through a string to be serialized.

Identifies volatile organic compounds (VOCs)

The device will also read at least one volatile organic compound (VOC). The goal is to be able to detect paint thinner or any VOC that relates to a building collapse scenario. For example, any chemicals left on burning wood could be a potential VOC. This target can be measured through the sensor and read in through a string to be serialized.

Measures in the amount of gas concentration

Once the gases are detected the system will have the ability to measure the amount of gas in the air. The ability to recognize and measure the amount of gas in PPM is important to keep the user safe. Once measured in PPM it can be compared against dangerous levels and this data will be used to save the user.

Sends signal to notification system

Commented [JN1]: Takes readings from LEL and UEL comparison to warn user if threaten. As well if gas is a VOC, it warns user

The gas detection system's ability to send signals to a notification system is a critical safety metric. It ensures that when dangerous gas levels are detected, alarms are triggered, and appropriate personnel who are wearing the device will be informed promptly. This feature can save lives and minimize the potential damage caused by gas-related incidents**.**

1.4.3 Method of Validation

To validate our targets, different methods will have to be used depending on the specific target. To validate our targets related to sensor inputs, we will expose the sensors to a known environment and compare sensor outputs to known air content. To validate our targets related to computational speed and volume, known test signals will be run through the system. Our output system will be validated through extensive testing to ensure reliability, as well as redundancy in code.

The inputs to our system are responsible for detecting gasses present in the surrounding atmosphere. A mixture of analog and digital sensors is likely to be used to detect these gases, so results will be measured via changes in voltage as well as through serial communication. Code will be written to input these signals to our computation center, where further processing will occur. To validate our input targets, we will place our sensors in a chamber with known gas content and our read values will be compared to the actual. There will be an error associated with this reading, this will be accounted for. Errors will be mitigated through various methods including taking RMS of read values over set intervals (not to delay sensor readings), twisted pairs for wires, and any other methods that can be practically applied.

For our computational system, targets will be assessed by inputting known quantities where outputs can be validated analytically. It will be difficult to real-time validate results in this program due to the variable nature of the data, so fixed values will be needed for testing. The code will be validated in stages to ensure that errors will not accumulate. This staged validation process will be used both in testing and application stages.

1.5 Concept Generation

Concept generation is an integral part of the design process that challenges students to think creatively. Considering the project's limitations and targets, our team brainstormed one hundred different ideas. From there we determined our high and medium fidelity concepts. The full list of ideas can be found in Appendix D: Concept Generation

1.5.1 Medium Fidelity Concepts

Concept 1 – Combustible Gas (CG) with O2 sensor, SBC, LiPo battery on a vest (#29)

All computational and sensing components will be placed on a vest, display will be mounted as decided by team 505. Using a vest allows for a larger battery and less obstruction of the user's range of motion than limb-mounted options. Mass will also be maintained close to the user's natural center of gravity.

Concept 2 - CG with O2 sensor, Microcontroller, LiPo battery in a boot (#42)

The components would be fitted into a boot giving us more space than a shoe would and would use a micro controller since an SBC would be unnecessary. It would then communicate with team 505's display in order to give necessary information from the sensors. The integration from the boots will also allow for an alarm to go off when gas concentration gets too high, this will specifically have an O2 sensor that would also test for air quality so the user will know when they need to get out of the building. Similar to other concepts there will be a LiPo battery in use, this helps with weight and the portability of the battery, it also ensures the battery will be powerful enough.

Concept 3 - CG with O2 sensor, SBC, LiPo battery on a removable clip (#66)

All sensing gas sensors feature a single board computing (SBC) which would have a lot of flexibility on how we can code the gas sensor. The design would fit on the waist which can clip on and off of belt loops or belt buckles and be very lightweight and portable. This board would also be able to communicate with the display and other functions with team 505 and be integrable. The battery would be somewhat heavy because it is a LiPo battery but would be powerful enough to have lasting hours on the sensor.

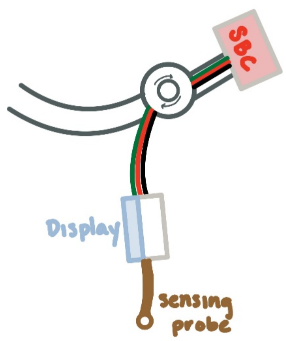


Figure 3: Concept 3

Concept 4 – CG with O2 sensor, Microcontroller, LiPo battery in a watch (#73)

Sensing vitals and gas sensor will be placed on the band of the watch. The display will be the face of the watch and be digital. Team 505 would create the display and the vitals of the user. We will create the interface of the gas sensor and the LiPo battery with the watch. The watch will also create a noise when detecting gas to notify user.

Concept 5 - CG with O2 sensor, Microcontroller, LiPo battery on a hat (#75)

Mounting a combustible gas sensor on a hat would prove advantageous, given that the gases it detects are predominantly located in the upper regions of the atmosphere. Moreover, placing the O2 sensor in close proximity to the face is crucial for accurately assessing the breathability levels in the surroundings. Opting for a microcontroller offers cost-effectiveness, lower power consumption, and ensures the device remains lightweight. Nevertheless, this is a medium fidelity as it imposes constraints on processing power and networking capabilities. Lastly, it introduces additional weight to the head, which is not ideal.

1.5.2 High Fidelity Concepts

Concept 6 - CG with O2 sensor, SBC, LiPo battery inside waist pack (#70)

All sensing, computing, and power components are held in a pack worn on the user's waist. This could integrate with tool belts already worn by search and rescue operators, adding little weight or restrictions on mobility.

Concept 7 – Isolated computer and battery that can be easily connected to multiple wearable configurations (#60)

Because many concepts will involve using the same general electrical hardware, a modular design will be created to connect a computer and battery pack to a range of wearable components. This will allow search and rescue operators to tailor their gas sensor experience to whatever platform suits them best. This idea was generated by considering the open nature of the project and the broad requirements of the sponsor.

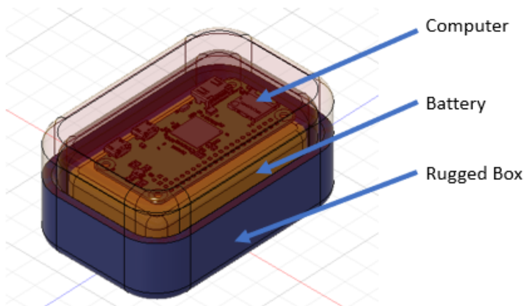


Figure 4: Concept 7

Concept 8 – Analog sensing for each desired gas detection chemicals will be placed on the inner arm (#12)

Rather than using a complex computational system to detect gases, an analog system can be used to detect gases. Different gases will react differently with other chemicals to change color, which can be taken advantage of to make clear gasses present in the air. A fluid reserve will be kept ensuring enough to allow a use time of over 18 hours. The user will be given a switch/bulb to press to release the chemical onto a test area that is exposed to the environment.

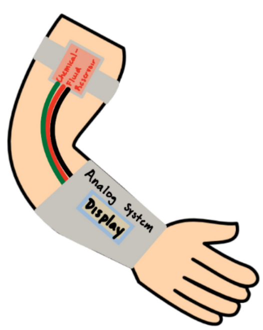


Figure 5: Concept 8

1.5.3 Concept Generation Tools

To help reach one hundred concepts we utilized a variety of different concept generation tools: crap-shoot, anti-problem, forced analogy, and a morphological chart.

Using crap-shooting, concepts were developed by naming existing articles of clothing that a search and rescue operator would be wearing, then determining if a gas sensor could be integrated into that article of clothing. This resulted in concepts such as integrating sensors into a helmet, arm sleeve, boot, and more. Using these concepts, we were able to better determine the expected size of our computational package, and where on the body a package of this nature would cause the least disruption to range of motion and mobility.

Using a morphological chart was helpful for determining the type of computational components to be used. There are many options for computers, sensors, power supplies, and mounting locations that needed to be considered, and a morphological chart provided useful insight. It was determined that using a microcontroller will limit our ability to store and process large amounts of data, so it was decided that an SBC will be necessary. Many sensor types exist, but the options within our price range that can interface with an SBC are more limited. It was decided that it would be best to decide on specific sensor types and products once a concept has been selected, as most have a comparable form factor.

Using anti-problem to generate ideas allowed us to see potential problems and generate ideas that would fix them. An example would be to ask ourselves, “How do we create a gas sensor to fail at detecting gas?” some answers to that would be to create a sensor that is easily blocked or a sensor that is affected by pressure or temperature. Considering these challenges resulted in the team coming up with different ideas that would fix certain problems that may arise when in our chosen scenario. Most of the questions that were asked during the anti-problem generation had to do with safety, meaning that this generation method was good for generating ideas with safety in mind.

Using forced analogy was helpful to come up with unique ideas that may not have been thought of without it. Forced analogy is the process of finding parallels between two unrelated concepts to spark ideas for other concepts. Some of the ideas on their own may not be the most likely design choices but components of the ideas would be good to incorporate into a final design. This helped us because instead of looking at these somewhat unrelated ideas we took them and found ways that they could be connected and that helped us to come up with other unique ideas.

Using these simplifying assumptions, our concept selection was narrowed to form factors that could house an SBC and appropriately sized battery (approximately 5000mah @ 5V) without hindering the user. Based on these new constraints, concepts were further generated to meet them, now focusing on where the sensors will be located. Most of the gases that will be detected are lighter than air, so there is a bias to higher mounting of the sensors relative to the user.

1.6 Concept Selection

To help us select a concept various design alternatives are evaluated to identify the most promising solution. This process involves several tools and methodologies to systematically assess and compare different concepts. Among these tools are the Binary Decision Diagram

(BDD), House of Quality (HoQ) chart, Pugh chart, Analytic Hierarchy Process (AHP) Main, and AHP Environmental Criteria (EC).

1.6.1 Binary Decision Chart

The Binary Decision Diagram (BDD) is a straightforward tool used for initial concept screening. It helps to quickly eliminate less viable options based on key criteria, narrowing down the choices to those with the most potential. The table has the customer requirements that we narrowed down from what was the most important to what was not as important. If you look at the table, you will see that to detect desired gases, identify desired gases, and warn the user are the top 3 customer requirements we deem to be important.

Customer Requirements	1	2	3	4	5	6	7	8	9	Total
Detect Desired Gases	-	1	1	1	1	1	1	1	1	8
Warn the User	0	-	1	1	1	1	1	1	0	6
Battery Life	0	0	-	0	1	0	0	0	0	1
Lightweight	0	0	0	-	1	1	1	1	0	4
User Friendly	0	0	1	0	-	1	0	1	0	3
Display Data Over Time	0	0	1	0	0	-	0	0	0	1
Withstand Realistic Temperatures	0	0	1	0	1	1	-	1	0	4
Data Transmission	0	0	1	0	0	1	0	-	0	2
Identify Desired Gases	0	1	1	1	1	1	1	1	-	7
Total	0	2	7	4	5	7	4	6	1	n - 1 :

Figure 6: Binary Pairwise Chart

1.6.2 House of Quality (HoQ)

The House of Quality (HoQ) chart serves as a comprehensive tool to translate customer requirements into tangible engineering characteristics. This graphical representation establishes a visual nexus between the articulated needs of the customer and the corresponding features integrated into the product. Its utility extends beyond mere illustration; the HoQ chart becomes a facilitator of cross-functional communication within the design team. By delineating the intricate relationships between customer needs and product attributes, it streamlines the decision-making process.

		Engineering Characteristic							
Improvement Direction		↑	-	↓	↑	↑↓	↓	↓	↑
Units		N/A	N/A	Sec	Wh	bits	Celsius	bits	ft
Customer Requirements	**Importance Weight Factor**	**Sensitivity**	**Selectivity**	**Response Time**	**Power Consumption**	**Data Logging**	**Withstand Temp Range**	**Data Transmission**	**Rugged/Durabl e**
Detect Desired Gases	**8**	9	9	9	9	3	3	9	9
Identify Desired Gasses	**7**	9	9	9	3	3	3	9	9
Warn the User	**6**	3	9	9	9	3	0	9	0
Battery Life	**1**	0	0	3	1	0	0	0	0
Lightweight	**4**	0	3	0	0	0	0	0	3
User Friendly	**3**	0	0	0	0	0	0	9	0
Display data over time	**1**	1	1	3	3	9	3	9	0
Withstand Realistic Temperatures	**4**	1	0	0	0	0	9	0	9
Data Transmission	**2**	9	3	3	3	3	1	9	9
Raw Score ()		176	208	201	157	78	86	243	201
Relative Weight %		13.04	15.41	14.89	11.63	5.78	6.37	18.00	14.89
Rank Order		5	2	3	6	8	7	1	3

Figure 7: House of Quality (HoQ)

The HoQ chart helps to identify the engineering characteristics that will be the most important to our final design. Data Transmission emerges as our foremost priority, crucial for conveying sensor readings to Team 505. Selectivity follows closely as the second-ranked characteristic, emphasizing the importance of discerning the gases at play. Tied for the third rank are Rugged/Durable and Response Time, underscoring the joint significance of durability and quick responsiveness in our sensors. Sensitivity claims the fifth position, vital for avoiding false alarms. Power consumption, securing the sixth rank, is pivotal for ensuring a prolonged battery life. Seventh in line is withstanding the desired temperature range, underscoring the importance of accurate data transmission even in extreme temperature conditions.

Lastly, for Data Logging, our priority lies in furnishing users with real-time data for immediate safety considerations, de-prioritizing extensive data storage. The device should be updated by the user in real time, while data logging is important that is at the bottom of our customer needs. This structured approach to prioritization within the HoQ chart ensures that the selected concept aligns meticulously with customer expectations and the overarching design objectives.

Engineering Charactersitics	Relative Weight (%)	Rank	Criteria (Average)		
Sensitivity	13.04	5	12.50		
Selectivity	15.41	2			
Response Time	14.89	3			
Power Consumption	11.63	6		**Legend**	
Data Logging	5.78	8			Keep
Withstand Temp Range	6.37	7			
Data Transmission	18.00	1			
Rugged/Durable	14.89	3			

Ordered Rank:	1	Data Transmission
	2	Selectivity
	3	Rugged/Durable
	3	Response Time
	5	Sensitivity
	6	Power Consumption
	7	Withstand Temp Range
	8	Data Logging

Figure 8: House of Quality Chart

1.6.3 Pugh chart

The Pugh chart, also known as the decision matrix, is a systematic method for evaluating and comparing multiple concepts against an existing datum. Each concept is compared to this datum, and a positive, negative, or equal score is assigned based on their relative advantages and disadvantages to the datum. The Pugh chart assists in quantifying design decisions and facilitates a structured approach to concept selection. Having the XP-702III Combustible Gas Handheld Detector as our baseline to compare our concept too this is what our Pugh chart came out to be.

Engineering Characteristics	Sensit Trak-It IIIa Combustible Gas Indicator	Concepts: Med 3 (SBC Clip)	High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
Data Transmission	- DATUM -	+	S	+	-
Selectivity		-	+	S	+
Rugged/Durable		S	+	+	+
Response Time		+	+	+	+
Sensitivity		-	-	S	-
Power Consumption		-	-	-	+
Withstand Temp Range		S	S	+	-
Data Logging		-	-	+	-
Total Pluses		2	3	5	4
Total Satisfactory		2	2	2	0
Total Minuses		4	3	1	4

Figure 9: Pugh Chart 1 Data

Engineering Characteristics	Sensit Trak-It IIIa Combustible Gas Indicator	Concepts: Med 3 (SBC Clip)	High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
Data Transmission	- DATUM -	+	S	+	-
Selectivity		-	+	S	+
Rugged/Durable		S	+	+	+
Response Time		+	+	+	+
Sensitivity		-	-	S	-
Power Consumption		-	-	-	+
Withstand Temp Range		S	S	+	-
Data Logging		-	-	+	-
Total Pluses		2	3	5	4
Total Satisfactory		2	2	2	0
Total Minuses		4	3	1	4

Figure 10: Pugh Chart 2 Data

In utilizing the XP-702III Combustible Gas Handheld Detector as our baseline for comparison, our Pugh chart reveals compelling insights. Notably, the High 2 concept (Isolated Box) emerges as a standout performer, showcasing the highest number of positives and minimal negatives across various criteria. This clear distinction positions High 2 as a frontrunner in our concept evaluation. Tied for the second position are the High 3 (Analog Inner Arm) and the (SBC Clip), both of which present viable alternatives for consideration. However, upon close examination, the High 2 (Isolated Box) concept stands out as the more logical choice, consistently proving to be superior across all evaluated categories.

A second Pugh chart was completed with the finalists from the initial chart, this chart used the Sensit Trak-It IIIa Combustible Gas Indicator as a datum. This second pugh chart has the most positive results for the isolated box concept. The strategic use of the Pugh chart enables us to make informed decisions, guiding us towards the most promising and effective concept for further development.

1.6.4 Analytic Hierarchy Process (AHP)

To further validate the selection methods used previously, AHP tables were used. Our main AHP tables established critical weights for each of the selected engineering characteristics. These weights are critical to understanding which characteristics will be the most important when delivering a final product. This tool also creates a consistency check, which is critical to validating the results in an objective and analytical manner. With a final consistency ratio of 0.093, our process is consistent across itself.

[C] Matrix										
	Analytical Hierarchy Process	A	A	A	A	A	A	A	A	
B	**Engineering Charactersitic**	Data Transmission	Selectivity	Rugged/Durable	Response Time	Sensitivity	Power Consumption	Withstand Temp Range	Data Logging	Average
B	Data Transmission	1	0.333	0.333	0.333	0.200	0.200	0.111	0.200	0.339
B	Selectivity	3	1	0.333	0.333	0.333	0.333	0.143	0.111	0.698
B	Rugged/Durable	3	3	1	0.333	0.333	0.333	0.200	0.111	1.039
B	Response Time	3	3	3	1	0.333	0.200	0.333	0.200	1.383
B	Sensitivity	5	3	3	3	1	0.333	0.200	0.333	1.983
B	Power Consumption	5	3	3	5	3	1	0.333	0.333	2.583
B	Withstand Temp Range	9	7	5	3	5	3	1	0.333	4.167
B	Data Logging	5	9	9	5	3	3	3	1	4.750
	Total	34.000	29.333	24.667	18.000	13.200	8.400	5.321	2.622	16.943
	Average	4.250	3.667	3.083	2.250	1.650	1.050	0.665	0.328	2.118

Figure 11: Analytical Hierarchy Process

norm[C] Matrix										
	Analytical Hierarchy Process	A	A	A	A	A	A	A	A	
B	Engineering Charactersitic	Data Transmission	Selectivity	Rugged/Durable	Response Time	Sensitivity	Power Consumption	Withstand Temp Range	Data Logging	Critical Weight {W}
B	Data Transmission	0.029	0.011	0.014	0.019	0.015	0.024	0.021	0.076	0.026
B	Selectivity	0.088	0.034	0.014	0.019	0.025	0.040	0.027	0.042	0.036
B	Rugged/Durable	0.088	0.102	0.041	0.019	0.025	0.040	0.038	0.042	0.049
B	Response Time	0.088	0.102	0.122	0.056	0.025	0.024	0.063	0.076	0.069
B	Sensitivity	0.147	0.102	0.122	0.167	0.076	0.040	0.038	0.127	0.102
B	Power Consumption	0.147	0.102	0.122	0.278	0.227	0.119	0.063	0.127	0.148
B	Withstand Temp Range	0.265	0.239	0.203	0.167	0.379	0.357	0.188	0.127	0.240
B	Data Logging	0.147	0.307	0.365	0.278	0.227	0.357	0.564	0.381	0.328
	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.283

Figure 12: Normalized Analytical Hierarchy Process

			Consistency Check		
Weighed Sum Vector {Ws} = [C]{W}	{W}	Cons = {Ws}./{W}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.220	0.026	8.430	8.906	0.129	0.093
0.308	0.036	8.548			
0.427	0.049	8.660			
0.613	0.069	8.832			
0.904	0.102	8.845			
1.378	0.148	9.307			
2.248	0.240	9.347			
3.047	0.328	9.282			

Figure 13: Consistency Check

1.6.5 AHP Environmental Criteria (AHP EC)

After the main AHP was completed, an additional EC table was created to generate design priorities by comparing the remaining concepts against each other in the context of different engineering characteristics. These comparisons help to generate design priorities, which can then be plugged into a pi matrix. The pi matrix is transposed and multiplied by the critical weights obtained in the main AHP to create an alternative value chart, ranking the ideas based on ranked criteria. This chart revealed that our ranking gives preference to the isolated box concept.

		[Pi] Matrix		
	Analytical Hierarchy Process	A	A	A
B	Engineering Charactersitic	High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Data Transmission	0.260	0.633	0.106
B	Selectivity	0.071	0.180	0.748
B	Rugged/Durable	0.261	0.633	0.106
B	Response Time	0.261	0.633	0.106
B	Sensitivity	0.283	0.643	0.074
B	Power Consumption	0.069	0.155	0.777
B	Withstand Temp Range	0.193	0.083	0.724
B	Data Logging	0.194	0.723	0.083
	Sum:	1.592	3.685	2.723

Figure 14: Pi Matrix

Concept	Alternative Value
Waist Strap	0.189
Isolated Box	0.444
Inner Arm	0.366156328

Figure 15: Final Alternative Values

1.6.6 Final Selection

Based on the results of our concept selection process, an isolated box to contain computational and power components with external sensors has been selected as the best option. The second option based on our alternative value chart is the analog arm sleeve. This option ranked so well due to its high selectivity, temperature resilience, and low power needs, but failed to meet the necessary standards for data transmission, logging, and response time.

Moving forwards with the isolated box concept, we will begin working on a code structure to accept data from all necessary sensors and design a box to house all required components. Once a code base has been developed, the code will be run on a variety of computer options to determine the performance and current draw of each, this will lead to final selection of a computer and battery. This multifaceted approach integrates software and hardware considerations, encompassing both code development and component selection. By subjecting the system to rigorous testing across diverse scenarios, we aim to refine and optimize the isolated box concept, laying the groundwork for a robust and efficient implementation in the final product.

1.7 Spring Project Plan

Chapter Two: EML 4552C

2.1 Spring Plan

Project Plan.

Build Plan.

Appendices

Appendix A: Code of Conduct

Mission Statement:

Our mission is to design and provide an innovative wearable solution to help our customers keep people safe from potentially hazardous gases.

Outside Obligations:

Each team member will be unavailable at the following times:

Benjamin Labiner: Tuesday and Thursday 2pm- 7pm

Michaela Porcelli: Mondays 9:30 AM - 4:15 PM; Tuesday and Thursday 11:30 AM - 3:30 PM; Wednesday 9:30-12:15 and 5:00-8:00 PM

Jane Nordhagen: Monday 11:15 AM – 12:15 PM; Wednesday 11:15 AM – 12:15 PM and 5:00-8:00 PM

Alex McIvor:

Monday, Wednesday, Friday 8:00 AM – 1:00 PM; Tuesday and Thursday 12:15 PM – 3:00 PM.

Shawn Butler: Mondays 8am-2pm, Tuesday 11am-8pm, Wednesday 8am-1-45pm, Thursday 11AM-8PM, and anytime Friday-Sunday

Deleted: Tuesdays and Thursdays 9:00 AM-7:45PM; Wednesdays: Noon-4:00PM; Friday 5:00 PM to Monday Noon

Deleted: Mondays and Wednesday 9 AM –2 PM; Tuesdays and Thursday 9:30-4:45

Deleted: Mondays and Wednesday 9AM – 3PM; Tuesday and Thursdays 9:30 - 8PM.

Deleted: Monday, Wednesdays, and Thursday 8:00 AM – 1:30 PM; Monday and Wednesday 3:30 PM – 4:45 PM; Friday 12:25 PM – 3:10 PM.

Deleted: 8am-2pm

Deleted: 8am

Deleted: 2PM

Deleted: 8PM

Deleted: 8

Team Roles:

Power Systems and Monitoring – Michaela Porcelli

Modular Box Design and Sensor Integration – Benjamin Labiner

Integration with team 505– Shawn Butler

Power Systems and Monitoring – Jane Nordhagen

Sensor Mounting and Clip Design– Alex McIvor

Deleted: Design Engineer

Deleted: Mechatronics Engineer

Deleted: Mechanical Engineer

Deleted: Purchasing & Research Engineer

Deleted: Test Engineer

Communications:

Our team will meet weekly in person and bi-weekly with our sponsors if they are available. Our main communication platform will be Microsoft Teams to discuss project assignments. Texting will be used for informal communication. Emails will be used for formal communication with sponsors and Dr. McConomy.

Dress Code:

During our presentations:

- We will wear business formal if the sponsor is present.
- We will wear business casual if the sponsor is absent.

For our online bi-weekly meeting online with our sponsor, we will wear casual.

Deleted: For sponsor meetings,

Deleted: we will wear business casual.

Attendance Policy:

- All team members are present when meeting with sponsors and all VDR presentations.

- Team meetings should have at least three members of the group present (All members should be there). Communicate if you cannot attend meetings; you must notify the group 24 hours in advance. We will reschedule the meeting if three or more members cannot attend.
- In extenuating circumstances, exceptions will be made. These circumstances must be effectively communicated to the group within 24 hours of the meeting.
- If known events will conflict with senior design meetings/classes, place them on their individual Outlook calendar and let the team know.

How to notify group:

- Main communication will be with Microsoft Teams regarding the project and assignments.
- Communication with sponsors will be through email and Google Meet if applicable (or sponsor's desired meeting platform).
- Canvas and email communications with Dr. McConomy will be used to contact him about anything we might need. Such as grade contentions or anything concerning the project.
- Informal communication will be through text messaging.

Deleted: Zoom

How to respond to people in professional meetings:

In Microsoft Teams, messages will be in a formal tone and appropriate language when communicating. Addressing each other by name, for example, "@Ben, can you …..." or "@All, did we...." When using the '@' symbol will notify members directly if something regards them if their chat logs are muted.

Regarding writing an email, we will state the subject title, "Subject of the conversation being talked about," and address it formally. "Dear [Name], we are contacting you to discuss...."

What do we do before Dr. McConomy or TAs:

Attempt to talk to the group to come to an understanding/conclusion about any pressing issues concerning our group. There will be three attempts to contact the person by email or Microsoft Teams. We will have formal documentation that is written and addressed to the person. Then, most of the team must conclude to give out a strike to a person.

At what point do we contact Dr. McConomy:

If we cannot agree on a topic where there is a 3/5 majority or have an issue, we will contact Dr. McConomy.

What do you want Dr. McConomy to do:

Give us input or advice on how to solve the problem, and if further action is needed, try to help us out as best as he can.

How to Amend:

The amending process must be presented to the group and in Microsoft Teams for tracking purposes. If the team wants to change anything stated in future documents or future work, we must have a majority rules vote(plurality, not majority).

Statement of Understanding:

"We agree that all group members have discussed everything written in this document and can be rediscussed and amended if majority conflicts; for example, if 3/5 members agree with a particular statement or action, then the majority rules."

Jung Typology Personality Tests:

Shawn Butler: ENTJ
Benjamin Labiner: INTJ
Alex McIvor: ISTJ
Jane Nordhagen: ENFJ
Michaela Porcelli: ESFP

Team Signatures:

Shawn Butler:

Benjamin Labiner:

Alex McIvor:

Jane Nordhagen:

Michaela Porcelli:

Appendix B: Functional Decomposition

Appendix C: Target Catalog

Note: The following table is the combination of Team 505 and Team 506's targets and metrics to meet the overall needs of the project/CIA. Team 506 is in blue and our critical targets are bolded. Team 505 is in the red.

System	Function	Target	Metric
Inputs	**Identifies combustible gases**	Focus on 3 combustible gases	Voltage
Inputs	**Identifies volatile organic compounds (VOCs)**	Focus on 1 VOC: paint thinners	Voltage
Computation	**Measures gas concentrations**	Read at least 300 parts per million (PPM)	PPM or volume %
Outputs	**Sends signal to notification system**	±10%	Margin of error
Outputs	Displays battery level	Warns user of battery life less than 20%	Voltage
Outputs	Displays current air status	±10%	Margin of error

Outputs	Displays the devices self-diagnosis	±10%	Margin of error
Structure	Durable	Able to withstand a 1 story drop without critical systems failing	Meters
Weight	Weight of the entire wearable device	Force (Weight)	< 40 lb.
Size	Physical volumetric dimensions of the device	Measure	Industry standard
Look	Aesthetic of the device	Physical appeal	Aesthetically pleasing
Durability	The strength of the device to withstand exposure to the elements	Physical strength	Can withstand exposure to search and rescue use
Material	Composition of device	Material	Durable material

Comfort	Comfortability of wearable device	Physical comfort	Moderate level of comfort for the user
Wearable	How the device feels and wears on the user	Physical wearable	Able to be worn in variety of scenarios
User Interface	Interface in which displays vital information for user	Time	< 10 sec.
Safety	Safety features associated with the device	Standard safety requirements for first responders	Meets field safety requirements
Data Collection	Collection and storage of user data	Time	Stores data for 1 hr. then overwrites
Power	Duration of power supply	Time	72 hr.

Appendix D: Work Break Down Structure

Evidence Book:

Date Due: 9/15/2023

Total Tasks: 25

Work Break Down Structure

Key: Ben | Shawn | Alex | Michaela | Jane

Canvas Link

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Ben	List all assignments in evidence book	1	
	Ben	Create excel doc with a sheet for each assignment	1	
	Ben	Create template for project completion and apply to all sheets	1	
	Ben	List tasks for Work Break Down Structure	1	
	Michaela	List tasks for Code of Conduct	1	
	Michaela	List tasks for Project Scope	1	
	Jane	List tasks for Customer Needs	1	
	Jane	List tasks for Functional Decomp	1	
	Shawn	List tasks for Targets	1	
	Ben	List tasks for Concept Generation	1	
	Jane	List tasks for Concept Selection	1	
	Alex	List tasks for Risk Assessment	1	
	Alex	List tasks for Bill of Materials	1	
	Jane	List tasks for Spring Project Plan	1	
	Shawn	List tasks for Poster	1	
	Ben	Sign up for Ben Tasks on each Assignment	1	Sign up for # of tasks/5 for each assignment
	Jane	Sign up for Jane Tasks on each Assignment	1	Sign up for # of tasks/5 for each assignment
	Alex	Sign up for Alex Tasks on each Assignment	1	Sign up for # of tasks/5 for each assignment
	Michaela	Sign up for Michaela Tasks on each Assignment	1	Sign up for # of tasks/5 for each assignment
	Shawn	Sign up for Shawn Tasks on each Assignment	1	Sign up for # of tasks/5 for each assignment
	Ben	Link each sheet to corresponding folder in Teams	1	
	Ben	Create link to canvas page on each assignment	1	

Date Due: 9/19/2023

Total Tasks: 19

Code of Conduct

Canvas Link

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Alex	Edit/Check Document	1	
	Shawn	Validate language used with third party	2	
	Jane	Create Title Page	1	
	Michaela	Create Table of Contents	1	
	Michaela	Write Mission Statement	1	
	Jane	Write Outside Obligations	1	
	Michaela	Assign Team Roles	1	
	Alex	Write Communication	1	
	Alex	Write Dress Code Policy	1	
	Michaela	Write Attendance Policy	1	
	Shawn	Write How to Notify Group	1	
	Shawn	Write How to Respond to People in Professional Meeting	1	
	Shawn	Write Statement of Understanding	1	
	Ben	Write What do we do before Dr. McConomy or TAs	1	
	Ben	Write At what point do we contact Dr. McConomy	1	
	Ben	Write What do you want Dr. McConomy to do when you come	1	
	Ben	Write How to amend code of conduct	1	

Date Due: 9/29/2023

Total Tasks: 11

Project Scope

Canvas Link

Assignment Description: Review lecture slides from EDM. This should reflect your interpretation of the project brief & the info from your customer

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Alex	Check for clarity and brevity	2	
	Ben	Write a project Description that is clear, concise, and understood by the public	1	
	Jane	Goals are stated early, clearly, understood, and support the project description	1	
	Michaela	Four markets similar to the project sponsor are identified	2	
	Shawn	Assumptions identified help control the scope of the project	2	
	Shawn	Stakeholders are found outside of original contacts	1	
	Alex	Connectivity extends between subject headings	1	
	Alex	Extra Effort	1	

Date Due: 10/11/2023

Total Tasks: 16

Customer Needs

Canvas Link

Assignment Descri; Concisely and professionally summarize your needs of your customer. Include the questions that you asked your customer, the response of your customer & how you are trying to tuen them into needs into a specificati

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes: Do not use the word "must" and "should"INe
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Shawn	Verify needs with the client	2	
	Ben	Come up 2 questions	2	
	Shawn	Come up 2 questions	2	
	Alex	Come up 2 questions	2	
	Michaela	Come up 2 questions	2	
	Jane	Come up 2 questions	2	
	Alex	Discuss questions as team	1	
	Alex	Interpreted Need	1	
	Jane	States "What" not "How": what the proj needs to do not how it will do it	3	
	Alex	Further narrow needs to single statement	2	
	Ben	Check nothing says "must" or "should"	1	
	Michaela	Check if interpreted needs use positive phrasing	1	
	Ben	Explanation of Results	1	

Date Due: 10/13/2023

Total Tasks: 18

Functional Decomposition

Canvas Link
Assignment Descri; The functions should be reflective of the product specifications, & the resolution be reflective of the project

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Shawn	Make sure low level functions start with a verb	1	
	Alex	Graphics	2	
	Michaela	Explanation of Results (must discuss the following 5 cells labled with a *)	1	
	Alex	Intro of F.D. provided *	2	
	Jane	Discussion of the data generation *	3	
	Michaela	Into of the graphics *	2	
	Alex	Discussion on how the F.D was gathered *	2	
	Shawn	Mentions function relations *	1	
	Ben	Connection to Systems: Documents how a series of functions relates to sub systems of the project	1	
	Ben	Smart Integration: highlights how functions will have cross sub-system relationships	2	
	Jane	Action and Outcome: describes physical action our expected outcome.	1	
	Shawn	Function Resolution: smallest element of the needed design system	1	
	Shawn	Communication	1	
	Michaela	Grammar	1	
	Ben	Extra Effort	1	

Date Due: 11/3/2023 Targets
Total Tasks: 16

Canvas Link
Assignment Descri; Once you have all of your functional begin to benchmark your project all targets to the functions. These are number with units. This should be very large spread that goes in the appendi

Status:	Person Assigned:	Task: A clear and concise overview of the specific goal or objective	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Shawn	Write Report	2	
	Shawn	Clarify the specific target or goal you want to achieve	1	
	Jane	Describe the purpose and importance of this target	3	
	Jane	Identify any constraints or limitations related to the target	2	
	Michaela	Break down the main target into smaller, measurable objectives	2	
	Ben	Ensure each objective is specific, measurable, achievable, relevant, and time-bound	1	
	Shawn	Identify the tasks or activities required to achieve each objective	3	
	Ben	List all the actions that need to be taken to move closer to the target(s)	2	
	Ben	Determine the priority of each objective and associated tasks	1	
	Jane	Establish a sequence or order in which tasks need to be completed	2	
	Alex	Identify the resources required for each task (e.g., time, budget, personnel, tools)	2	
	Alex	Allocate resources effectively to ensure successful execution	1	
	Michaela	Create a timeline or schedule for completing each task and objective	1	
	Alex	Define milestones to track progress and celebrate achievements along the way	2	

Date Due: 11/10/2023 Concept Generation
Total Tasks: 23

Canvas Link
Assignment Descri; This is organized brainstorming. Capture as many ideas as possible and then refine them. As you refine you should provide your justification for the exclusion of your ideas. The goal is

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Michaela	Write Report	1	
	Ben	Generate 20 Concepts	3	
	Shawn	Generate 20 Concepts	3	
	Alex	Generate 20 Concepts	3	
	Michaela	Generate 20 Concepts	3	
	Jane	Generate 20 Concepts	3	
	Alex	Compare concepts and remove repeats	1	
	Alex	Generate more ideas to replace removed ones	2	
	Ben	Vote for top 7 Medium fidelity concepts	2	
	Shawn	Vote for top 7 Medium fidelity concepts	2	
	Alex	Vote for top 7 Medium fidelity concepts	2	
	Michaela	Vote for top 7 Medium fidelity concepts	2	
	Jane	Vote for top 7 Medium fidelity concepts	2	
	Ben	Select final 5 medium fidelity concepts from votes	1	
	Ben	Vote for top 5 high fidelity concepts	3	
	Shawn	Vote for top 5 high fidelity concepts	3	
	Alex	Vote for top 5 high fidelity concepts	3	
	Michaela	Vote for top 5 high fidelity concepts	3	
	Jane	Vote for top 5 high fidelity concepts	3	
	Ben	Select final 3 high fidelity concepts from votes	1	
	Shawn	Colate list of concept generation tools from team	1	
	Jane	Communication/readability check	1	

Date Due: 11/10/2023 Concept Selection
Total Tasks: 13

Canvas Link
Assignment Descri; Through the process of engineering decision making document and designate one concept as the "winner".

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Shawn	Write Report	2	
	Alex	Encourage group to take buffer time	1	
	Michaela	Binary Pairwise Comparison	2	
	Ben	H.O.Q	2	
	Ben	Pugh Charts Iteration 1	1	
	Jane	Pugh Chart Iteration 2	1	
	Jane	AHP	2	
	Alex	Criteria Comparison (the amount of these will vary, will split evenly as we know more)	1	
	Michaela	Pugh Chart Iteration 3 (# will also vary: TBD)	1	
	Shawn	Final Selection	1	

Date Due: 11/24/2023 Risk Assessment Risk Assessment
Total Tasks: 12

Canvas Link
Assignment Descri: The functions should be reflective of the product specifications, & the resolution be reflective of the project

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Shawn	Make sure low level functions start with a verb	1	
	Alex	Graphics	2	
	Michaela	Explanation of Results (must discuss the following 5 cells labled with a *)	1	
	Alex	Intro of F.D. provided *	2	
	Jane	Discussion of the data generation *	3	
	Michaela	Into of the graphics *	2	
	Alex	Discussion on how the F.D was gathered *	2	
	Shawn	Mentions function relations *	1	
	Ben	Connection to Systems: Documents how a series of functions relates to sub systems of the project	1	
	Ben	Smart Integration: highlights how functions will have cross sub-system relationships	2	
	Jane	Action and Outcome: describes physical action our expected outcome.	1	
	Shawn	Function Resolution: smallest element of the needed design system	1	
	Shawn	Communication	1	
	Michaela	Grammar	1	
	Ben	Extra Effort	1	

Date Due: 11/3/2023 **Targets**
Total Tasks: 16

Canvas Link
Assignment Descri: Once you have all of your functional begin to benchmark your project all targets to the functions. These are number with units. This should be very large spread that goes in the appendi

Status:	Person Assigned:	Task: A clear and concise overview of the specific goal or objective	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Shawn	Write Report	2	
	Shawn	Clarify the specific target or goal you want to achieve	1	
	Jane	Describe the purpose and importance of this target	3	
	Jane	Identify any constraints or limitations related to the target	2	
	Michaela	Break down the main target into smaller, measurable objectives	2	
	Ben	Ensure each objective is specific, measurable, achievable, relevant, and time-bound	1	
	Shawn	Identify the tasks or activities required to achieve each objective	3	
	Ben	List all the actions that need to be taken to move closer to the target(s)	2	
	Ben	Determine the priority of each objective and associated tasks	1	
	Jane	Establish a sequence or order in which tasks need to be completed	2	
	Alex	Identify the resources required for each task (e.g., time, budget, personnel, tools)	2	
	Alex	Allocate resources effectively to ensure successful execution	1	
	Michaela	Create a timeline or schedule for completing each task and objective	1	
	Alex	Define milestones to track progress and celebrate achievements along the way	2	

Date Due: 11/10/2023 **Concept Generation**
Total Tasks: 23

Canvas Link
Assignment Descri: This is organized brainstorming. Capture as many ideas as possible and then refine them. As you refine you should provide your justification for the exclusion of your ideas. The goal is

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Michaela	Write Report	1	
	Ben	Generate 20 Concepts	3	
	Shawn	Generate 20 Concepts	3	
	Alex	Generate 20 Concepts	3	
	Michaela	Generate 20 Concepts	3	
	Jane	Generate 20 Concepts	3	
	Alex	Compare concepts and remove repeats	1	
	Alex	Generate more ideas to replace removed ones	2	
	Ben	Vote for top 7 Medium fidelity concepts	2	
	Shawn	Vote for top 7 Medium fidelity concepts	2	
	Alex	Vote for top 7 Medium fidelity concepts	2	
	Michaela	Vote for top 7 Medium fidelity concepts	2	
	Jane	Vote for top 7 Medium fidelity concepts	2	
	Ben	Select final 5 medium fidelity concepts from votes	1	
	Ben	Vote for top 5 high fidelity concepts	3	
	Shawn	Vote for top 5 high fidelity concepts	3	
	Alex	Vote for top 5 high fidelity concepts	3	
	Michaela	Vote for top 5 high fidelity concepts	3	
	Jane	Vote for top 5 high fidelity concepts	3	
	Ben	Select final 3 high fidelity concepts from votes	1	
	Shawn	Colate list of concept generation tools from team	1	
	Jane	Communication/readability check	1	

Date Due: 11/10/2023 **Concept Selection**
Total Tasks: 13

Canvas Link
Assignment Descri: Through the process of engineering decision making document and designate one concept as the "winner".

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Shawn	Write Report	2	
	Alex	Encourage group to take buffer time	1	
	Michaela	Binary Pairwise Comparison	2	
	Ben	H.O.Q	2	
	Ben	Pugh Charts Iteration 1	1	
	Jane	Pugh Chart Iteration 2	1	
	Jane	AHP	2	
	Alex	Criteria Comparison (the amount of these will vary, will split evenly as we know more)	1	
	Michaela	Pugh Chart Iteration 3 (# will also vary: TBD)	1	
	Shawn	Final Selection	1	

Date Due: 11/24/2023 **Risk Assessment** **Risk Assessment**
Total Tasks: 12

Canvas Link
Assignment Descri; The functions should be reflective of the product specifications, & the resolution be reflective of the project

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Shawn	Make sure low level functions start with a verb	1	
	Alex	Graphics	2	
	Michaela	Explanation of Results (must discuss the following 5 cells labled with a *)	1	
	Alex	Intro of F.D. provided *	2	
	Jane	Discussion of the data generation *	3	
	Michaela	Into of the graphics *	2	
	Alex	Discussion on how the F.D was gathered *	2	
	Shawn	Mentions function relations *	1	
	Ben	Connection to Systems: Documents how a series of functions relates to sub systems of the project	1	
	Ben	Smart integration: highlights how functions will have cross sub-system relationships	2	
	Jane	Action and Outcome: describes physical action our expected outcome.	1	
	Shawn	Function Resolution: smallest element of the needed design system	1	
	Shawn	Communication	1	
	Michaela	Grammar	1	
	Ben	Extra Effort	1	

Date Due: 11/3/2023 Targets
Total Tasks: 16

Canvas Link
Assignment Descri; Once you have all of your functional begin to benchmark your project all targets to the functions. These are number with units. This should be very large spread that goes in the appendi

Status:	Person Assigned:	Task: A clear and concise overview of the specific goal or objective	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Shawn	Write Report	2	
	Shawn	Clarify the specific target or goal you want to achieve	1	
	Jane	Describe the purpose and importance of this target	3	
	Jane	Identify any constraints or limitations related to the target	2	
	Michaela	Break down the main target into smaller, measurable objectives	2	
	Ben	Ensure each objective is specific, measurable, achievable, relevant, and time-bound	1	
	Shawn	Identify the tasks or activities required to achieve each objective	3	
	Ben	List all the actions that need to be taken to move closer to the target(s)	2	
	Ben	Determine the priority of each objective and associated tasks	1	
	Jane	Establish a sequence or order in which tasks need to be completed	2	
	Alex	Identify the resources required for each task (e.g., time, budget, personnel, tools)	2	
	Alex	Allocate resources effectively to ensure successful execution	1	
	Michaela	Create a timeline or schedule for completing each task and objective	1	
	Alex	Define milestones to track progress and celebrate achievements along the way	2	

Date Due: 11/10/2023 Concept Generation
Total Tasks: 23

Canvas Link
Assignment Descri; This is organized brainstorming. Capture as many ideas as possible and then refine them. As you refine you should provide your justification for the exclusion of your ideas. The goal is

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Michaela	Write Report	1	
	Ben	Generate 20 Concepts	3	
	Shawn	Generate 20 Concepts	3	
	Alex	Generate 20 Concepts	3	
	Michaela	Generate 20 Concepts	3	
	Jane	Generate 20 Concepts	3	
	Alex	Compare concepts and remove repeats	1	
	Alex	Generate more ideas to replace removed ones	2	
	Ben	Vote for top 7 Medium fidelity concepts	2	
	Shawn	Vote for top 7 Medium fidelity concepts	2	
	Alex	Vote for top 7 Medium fidelity concepts	2	
	Michaela	Vote for top 7 Medium fidelity concepts	2	
	Jane	Vote for top 7 Medium fidelity concepts	2	
	Ben	Select final 5 medium fidelity concepts from votes	1	
	Ben	Vote for top 5 high fidelity concepts	3	
	Shawn	Vote for top 5 high fidelity concepts	3	
	Alex	Vote for top 5 high fidelity concepts	3	
	Michaela	Vote for top 5 high fidelity concepts	3	
	Jane	Vote for top 5 high fidelity concepts	3	
	Ben	Select final 3 high fidelity concepts from votes	1	
	Shawn	Colate list of concept generation tools from team	1	
	Jane	Communication/readability check	1	

Date Due: 11/10/2023 Concept Selection
Total Tasks: 13

Canvas Link
Assignment Descri; Through the process of engineering decision making document and designate one concept as the "winner".

Status:	Person Assigned:	Task:	Time To Complete: (Days)	Notes:
	Ben	Submit Document	1	
	Jane	File Name Format	1	SD T506 yymmdd file description.extention
	Michaela	Edit/Check Document	1	
	Shawn	Write Report	2	
	Alex	Encourage group to take buffer time	1	
	Michaela	Binary Pairwise Comparison	2	
	Ben	H.O.Q	2	
	Ben	Pugh Charts Iteration 1	1	
	Jane	Pugh Chart Iteration 2	1	
	Jane	AHP	2	
	Alex	Criteria Comparison (the amount of these will vary, will split evenly as we know more)	1	
	Michaela	Pugh Chart Iteration 3 (# will also vary: TBD)	1	
	Shawn	Final Selection	1	

Date Due: 11/24/2023 Risk Assessment Risk Assessment
Total Tasks: 12

Appendix E: Concept Generation

1. Plate with sensors required under steel mesh similar to MQ-5 sensor.
2. Sensor placed on flying drone (drone can be body mounted) with sensors on flying drone and on backpack.
3. Sensor placed on driving drone (drone can be body mounted) with sensors on driving drone and on backpack.
4. Sensors fit into wrist-cuff with battery and computer remote.
5. Sensors go into a hazmat suit, allowing for different locations of sensors based on density
6. Sensors go in a helmet, batteries on hip with computer.
7. Sensors are located on belt along with computer and battery.
8. Belt based sensor on an extendable wire that can be attached to a cane
9. Sensors mounted on a necklace, fully self-contained with battery and computer.
10. Sensors mounted below mesh sleeve in backpack along with battery.
11. Modular computer + battery holder that can be incorporated into multiple wearable designs.
12. Analog sensing for each desired gas, no computational components required, detection chemicals will be placed on inner arm. (limited time for usage)
13. Belt mounted computer (Guarded) with multiple batteries for prolonged battery life with sensors included in suspender straps.
14. Mount gas sensor in shoelaces
15. Mount gas sensor in a full pair of shoes
16. Mount gas sensor in a fanny pack type bag mid-level on the body
17. Gas sensors mounted on helmet and shoes to test for gases at both levels to compare
18. Shirt with nano gas sensors that will change the color of the shirt when it detects gas
19. Leg braces that take control of your legs to get you out of the building when gas is detected
20. Pants that change color when gas is detected
21. Gas sensor mounted into a tie clip
22. Gas sensor mounted into cuff links
23. Gas sensor mounted into a tie
24. Holographic that comes up to tell you there is gas
25. Face mask with an integrated gas sensor
26. Gas sensor mounted in a cane
27. A spray you spray into the room and changes color when hit by gas
28. Attach a combustible gas sensor, SBC, LiPo battery inside a vest
29. A robot that picks you up and takes you out of the room when gas is detected
30. A bubble that blows up around you that has air filters
31. A vacuum to suck out all the gas before going in
32. Gas sensor mounted into a full suit
33. Shoulder straps that have a gas sensor on it
34. Handbag gas sensor out of it that can sense the gas

35. Knee brace with gas sensor integrated on the outside of it detecting dense gasses on the ground
36. Gas sensing watch band with the sensor in the band sensing gases above the waist
37. Gas sensor embedded knee pads detecting dense gasses on the ground
38. Sensor mounted in an earpiece detecting gases near head level
39. Gas sensor arm band with the sensor inside the band
40. Sensor placed inside a vest can be on the lower vest or near the straps of the vest
41. Attach a combustible gas sensor, SBC, LiPo battery inside a boot
42. Gas sensor in a onesie which can detect gasses anywhere
43. Hazmat suit with integrated gas sensor and respirator.
44. Sensor integrated into a T-shirt
45. Compact hair tie gas sensor
46. Gas sensor earrings
47. Sensor integrated into a ring (gas sensor ring)
48. Gloves with the sensor inside
49. Glasses integrated with gas sensor
50. Helmet visor screen with gas sensor on integrated
51. Lanyard with a sensor inside of it can be removed and detect different density levels
52. Ankle bracelet gas sensor decting low dense gasses
53. Jacket with gas sensor built into it can detect different density high, medium or low-level gasses
54. Sensor mounted on hair clip/headband
55. Handheld sensor like Ghostbusters sensor
56. Sensor mounted on water bottle
57. Dog collar gas sensor that's transmits data
58. Phone case that uses charge of phone to charge the gas sensor on it
59. DVD Case of Cars (2006) with gas sensor where the DVD slot is
60. Isolated computer and battery that can be easily connected to multiple wearable configurations
61. Squishmallow of PawPatrol character Chase with computer and battery mounted in
62. Firefighter Gas Mask with sensor on it
63. Firefighter helmet with sensor in it and very fireproof
64. Go-Pro Camera with sensor on strap
65. Attach a combustible gas sensor, SBC, LiPo battery on a removable clip
66. Gas sensor in pen or pencil in the eraser
67. Nail Polish that changes colors
68. New York Yankees baseball cap with sideburns where the gas sensor is
69. Attach a combustible gas sensor, SBC, LiPo battery inside a waist pack
70. Sunglasses that can see the gasses and visually detect them
71. Scarf weaved gas sensor on it
72. Attach a combustible gas sensor, SBC, LiPo battery inside a watch
73. Bowtie that glows red in the center when gas is present
74. Attach a combustible gas sensor, SBC, LiPo battery on a hat
75. Umbrella gas sensor on tip and wires are weaved into tarp (Waterproof)

76. Attach a sensor to a smartphone
77. Use catalytic bead sensors to detect combustible gases attached to handheld device
78. Send a canary bird with a match into the field first
79. Create augmented reality glasses equipped with gas sensors
80. Implement Micro-Electro-Mechanical Systems (MEMS) Sensors into flexible fabric
81. Use bimetallic strips that bend when they get in contact to gases
82. Attach Flame Ionization Detectors (FID) to a yoyo to detect gas
83. Attach thermal conductivity sensors to a vest
84. Use infrared cameras that analyze the changes in thermal radiation emitted
85. Implement gas tracer dyes into the equipment
86. Hot wire anemometer inside shoelaces
87. Have canine assistance to smell the field for gases
88. Place electrochemical sensors inside body armor
89. Use metal oxide semiconductor (MOS) sensors to target VOCs attached to a helmet
90. Sense gases uses a Photoionization Detectors (PID) to target VOCs inside a briefcase
91. Attach solid state sensors implicated into fanny pack
92. Have gas selective electrodes attached to a clip
93. Integrate an infra-red combustible sensor inside a watch
94. Continuously spray a bottle filled with water and soap to see if any bubbles formed
95. Attach a surface acoustic wave sensors attached to a belt
96. Have a nanostructured materials sensors attached to a RC car
97. Integrate a device that changes in resistance when exposed to gas
98. Design a flexible and wearable NO2 watch device
99. Create a boomerang attached with gas sensors
100. Integrate a miniaturized chemiresistor sensor into a wearable component
101. Use a gas-selective electrochemical cell on a chip

Computational/Electrical Concepts

*MQ-5 sensor is semiconductor and Gravity I2C sensor is electrochemical

1. A Catalytic bead CG sensor with a paramagnetic O2 sensor controlled by a SBC that displays results via single color LEDs and an LCD display, powered by a LiPo battery.
2. A Semiconductor CG sensor with an electrochemical O2 sensor controlled by a SBC that displays results via single color LEDs and an E-Paper display, powered by a LiPo battery.
3. A Semiconductor CG sensor with an electrochemical O2 sensor controlled by a SBC that displays results via color-changing LEDs and a flexible E-Paper display, powered by a LiPo battery.
4. A Semiconductor CG sensor with an electrochemical O2 sensor controlled by a SBC that displays results via color-changing LEDs and a touch screen display, powered by a LiPo battery.
5. A Semiconductor CG sensor with an electrochemical O2 sensor controlled by a microcontroller that displays results via LED dot matrix powered by a LiPo battery.

6. A Semiconductor CG sensor with an electrochemical O2 sensor controlled by a SBC that notifies user via speaker and single-color LEDs, powered by a LiPo battery.
7. A Semiconductor CG sensor with an electrochemical O2 sensor controlled by a microcontroller that notifies user via LED matrix display and color-changing LEDs, powered by a LiPo battery.

**These concepts are yielding results that indicate a strong benefit to using a SBC with a LiPo battery. It has also been found that deciding on a specific sensor type is limiting to specific hardware available, and it will be better to select a concept then choose specific sensors to match the application. **

Morphological Chart:

Detect Combustible Gasses	Detect Oxygen	Computation Options (SBC or Microcontroll er)	Notificati on (non-read out)	Notification (read-out)	Additional Component s (features)	Battery
Catal ytic Bead Sensor	Par amagnetic Sensor	Pi Pico	1 Color LEDs	LCD	The rmometer	LiPo *Cl A expressed preference*
IR Gas Sensor	Ele ctrochemic al Sensor	Pi Zero	S peaker	E-Paper	IMU	Stan dard (AA, AAA, D)
Semi conductor Sensor	Zir conia Sensor	Pi 4/5B	O ffset Mass (Vibrates)	Flex ible E-Paper	IR Camera	186 50 Series
Ther mal Conductivity Sensor	Flu orescence-Based Sensor	Ardui no 2560 Mega	C hanging color LED	Tou ch Screen	RF Communica tion	Lithi um Ion
Flam e Ionization Detector	Op tical Fiber Sensor	Ardui no Micro		LED Matrix Display		Lea d Acid
Ultra sonic Sensor		Ardui no Portenta		7-segment display		

		Beagle Bone				

Appendix F: Concept Selection

[C] Matrix for Sensitivity

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.333	5.000
B	Isolated Box	3.000	1	7.000
B	Inner Arm	0.200	0.143	1
	Total	4.200	1.476	13.000
	Average	1.400	0.492	4.333

[C] Matrix for Selectivity

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.333	0.111
B	Isolated Box	3.000	1	0.200
B	Inner Arm	9.000	5.000	1
	Total	13.000	6.333	1.311
	Average	4.333	2.111	0.437

[C] Matrix for Response Time

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.333	3.003
B	Isolated Box	3.000	1	5.000
B	Inner Arm	0.333	0.200	1
	Total	4.333	1.533	9.003
	Average	1.444	0.511	3.001

[C] Matrix for Power Consumption

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.333	0.111
B	Isolated Box	3.000	1	0.143
B	Inner Arm	9.000	7.000	1
	Total	13.000	8.333	1.254
	Average	4.333	2.778	0.418

[C] Matrix for Data Logging

	Analytical Hierarchy Process	A	A	A

[C] Matrix for Sensitivity

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.333	5.000
B	Isolated Box	3.000	1	7.000
B	Inner Arm	0.200	0.143	1
	Total	4.200	1.476	13.000
	Average	1.400	0.492	4.333

[C] Matrix for Selectivity

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.333	0.111
B	Isolated Box	3.000	1	0.200
B	Inner Arm	9.000	5.000	1
	Total	13.000	6.333	1.311
	Average	4.333	2.111	0.437

[C] Matrix for Response Time

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.333	3.003
B	Isolated Box	3.000	1	5.000
B	Inner Arm	0.333	0.200	1
	Total	4.333	1.533	9.003
	Average	1.444	0.511	3.001

[C] Matrix for Power Consumption

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.333	0.111
B	Isolated Box	3.000	1	0.143
B	Inner Arm	9.000	7.000	1
	Total	13.000	8.333	1.254
	Average	4.333	2.778	0.418

[C] Matrix for Data Logging

	Analytical Hierarchy Process	A	A	A

B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.200	3.030
B	Isolated Box	5.000	1	7.000
B	Inner Arm	0.330	0.143	1
	Total	6.330	1.343	11.030
	Average	2.110	0.448	3.677

[C] Matrix for Withstand Temp Range

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	3.000	0.200
B	Isolated Box	0.333	1	0.143
B	Inner Arm	5.000	7.000	1
	Total	6.333	11.000	1.343
	Average	2.111	3.667	0.448

[C] Matrix for Data Transmission

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.333	3.000
B	Isolated Box	3.000	1	5.000
B	Inner Arm	0.333	0.200	1
	Total	4.333	1.533	9.000
	Average	1.444	0.511	3.000

[C] Matrix for Rugged/Durable

	Analytical Hierarchy Process	A	A	A
B		High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)
B	Waist Strap	1	0.333	3.003
B	Isolated Box	3.000	1	5.000
B	Inner Arm	0.333	0.200	1
	Total	4.333	1.533	9.003
	Average	1.444	0.511	3.001

Average	
2.111	
3.667	
0.448	
6.225	

If COLUMN is more important then put a **BIG NUMBER**

If ROW is more important then put a **RECIPROCAL NUMBER**

	Analytical Hierarchy Process
B	
B	Waist Strap
B	Isolated Box
B	Inner Arm
	Total

Average	
0.481	
1.400	
5.000	
6.881	

If COLUMN is more important then put a **BIG NUMBER**

If ROW is more important then put a **RECIPROCAL NUMBER**

	Analytical Hierarchy Process
B	
B	Waist Strap
B	Isolated Box
B	Inner Arm
	Total

no

Average	
1.445	
3.000	
0.511	
4.956	

If COLUMN is more important then put a **BIG NUMBER**

If ROW is more important then put a **RECIPROCAL NUMBER**

	Analytical Hierarchy Process
B	
B	Waist Strap
B	Isolated Box
B	Inner Arm
	Total

norm

Average	
0.481	
1.381	
5.667	
7.529	

If COLUMN is more important then put a **BIG NUMBER**

If ROW is more important then put a **RECIPROCAL NUMBER**

	Analytical Hierarchy Process
B	
B	Waist Strap
B	Isolated Box
B	Inner Arm
	Total

n

	Analytical Hierarchy Process

Average
1.410
4.333
0.491
6.234

If COLUMN is more important then put a **BIG NUMBER**

If ROW is more important then put a **RECIPROCAL NUMBER**

B	
B	Waist Strap
B	Isolated Box
B	Inner Arm
	Total

norm[(

Average
1.400
0.492
4.333
6.225

If COLUMN is more important then put a **BIG NUMBER**

If ROW is more important then put a **RECIPROCAL NUMBER**

	Analytical Hierarchy Process
B	
B	Waist Strap
B	Isolated Box
B	Inner Arm
	Total

nori

Average
1.444
3.000
0.511
4.956

If COLUMN is more important then put a **BIG NUMBER**

If ROW is more important then put a **RECIPROCAL NUMBER**

	Analytical Hierarchy Process
B	
B	Waist Strap
B	Isolated Box
B	Inner Arm
	Total

noi

Average
1.445
3.000
0.511
4.956

If COLUMN is more important then put a **BIG NUMBER**

If ROW is more important then put a **RECIPROCAL NUMBER**

	Analytical Hierarchy Process
B	
B	Waist Strap
B	Isolated Box
B	Inner Arm
	Total

norm[C] Matrix for Sensitivity

A	A	A	
High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)	Design Alternative Priorities {Pi}
0.238	0.226	0.385	0.283
0.714	0.677	0.538	0.643
0.048	0.097	0.077	0.074
1.000	1.000	1.000	1.000

norm[C] Matrix for Selectivity

A	A	A	
High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)	Design Alternative Priorities {Pi}
0.077	0.053	0.085	0.071
0.231	0.158	0.153	0.180
0.692	0.789	0.763	0.748
1.000	1.000	1.000	1.000

ırm[C] Matrix for Response Time

A	A	A	
High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)	Design Alternative Priorities {Pi}
0.231	0.217	0.334	0.261
0.692	0.652	0.555	0.633
0.077	0.130	0.111	0.106
1.000	1.000	1.000	1.000

ı[C] Matrix for Power Consumption

A	A	A	
High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)	Design Alternative Priorities {Pi}
0.077	0.040	0.089	0.069
0.231	0.120	0.114	0.155
0.692	0.840	0.797	0.777
1.000	1.000	1.000	1.000

orm[C] Matrix for Data Logging

A	A	A	

High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)	Design Alternative Priorities {Pi}
0.158	0.149	0.275	0.194
0.790	0.745	0.635	0.723
0.052	0.106	0.091	0.083
1.000	1.000	1.000	1.000

C] Matrix for Withstand Temp Range

A	A	A	
High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)	Design Alternative Priorities {Pi}
0.158	0.273	0.149	0.193
0.053	0.091	0.106	0.083
0.789	0.636	0.745	0.724
1.000	1.000	1.000	1.000

n[C] Matrix for Data Transmission

A	A	A	
High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)	Design Alternative Priorities {Pi}
0.231	0.217	0.333	0.260
0.692	0.652	0.556	0.633
0.077	0.130	0.111	0.106
1.000	1.000	1.000	1.000

rm[C] Matrix for Rugged/Durable

A	A	A	
High 1 (SBC Waist Strap)	High 2 (Isolated Box)	High 3 (Analog Inner Arm)	Design Alternative Priorities {Pi}
0.231	0.217	0.334	0.261
0.692	0.652	0.555	0.633
0.077	0.130	0.111	0.106
1.000	1.000	1.000	1.000

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.866	0.283	3.062	3.066	0.033	0.063
2.008	0.643	3.121			
0.222	0.074	3.013			

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.215	0.071	3.006	3.029	0.015	0.028
0.544	0.180	3.017			
2.293	0.748	3.065			

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.790	0.261	3.033	3.039	0.019	0.037
1.946	0.633	3.072			
0.320	0.106	3.011			

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.206	0.069	3.013	3.082	0.041	0.079
0.471	0.155	3.043			
2.477	0.777	3.190			

Consistency Check

Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.590	0.194	3.044			
2.274	0.723	3.145	3.068	0.034	0.065
0.250	0.083	3.014			

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.588	0.193	3.043			
0.251	0.083	3.014	3.066	0.033	0.063
2.273	0.724	3.141			

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.790	0.260	3.033			
1.946	0.633	3.072	3.039	0.019	0.037
0.320	0.106	3.011			

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.790	0.261	3.033			
1.946	0.633	3.072	3.039	0.019	0.037
0.320	0.106	3.011			

References

There are no sources in the current document.