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			
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	12.50		
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.

		Concepts			
Engineering Characteristics	Sensit Trak-It IIIa Combustible Gas Indicator	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

		Concepts			
Engineering Characteristics	Sensit Trak-It IIIa Combustible Gas Indicator	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.