1.6 Concept Selection

Now that medium-fidelity and high-fidelity concepts have been selected, the team will use different analytical techniques to weigh each concept and decide on a final selection. These techniques include the House of Quality (HOQ), Pugh Charts, and the Analytical Hierarchy Process (AHP).

1.6.1 Binary Pairwise Comparison

Individual weight factors (IWF) for each of the designs must be generated to gauge how important each design characteristic is to have a functional product. The values in the gray corner were decided by pitting each design characteristic against itself and all the other design characteristics. If the characteristic in the row was said to be more important than the characteristic in the column, a 1 was assigned. For the inverse a 0 was assigned. The values in the yellow corner are mirrored inverses of the values in the gray corner. Each row was summed to acquire an IWF value for each design characteristic. IWF values will be used to scale values assigned in the House of Quality. Figure 8 shows the binary pairwise chart.

Interpreted Customer Needs	1	2	3	4	5	6	7	8	9	IWF
1. Waterproof	-	1	1	0	0	1	0	0	1	4
2. Versatility of Environment	0	-	0	0	0	0	0	0	1	1
3. Path Optimization	0	1	-	1	1	0	1	0	1	5
4. Center of Pressure Tracked	1	1	0	-	0	0	0	0	1	3
5. Motion of Glider Tracked	1	1	0	1	-	0	1	0	0	4
6. Survivability	0	1	1	1	1	-	1	1	1	7
7. Depth	1	1	0	1	0	0	-	0	1	4
8. Simulation	1	1	1	1	1	0	1	-	1	7
9. Track Temperature of Environment	0	0	0	0	1	0	0	0	-	1
Total	4	7	3	5	4	1	4	1	7	n-1=8

Figure 8: Binary Pairwise Comparison

1.6.2 House of Quality

The House of Quality's purpose is to investigate the relationship between customer needs and the engineering characteristics defined by the group. To weigh the correlation between each need and characteristic, a relative weight is assigned to the intersection of the respective row and column. The weights are given the values of one, three, and nine. One indicates a low level of correlation between the customer's need and the characteristic, and nine indicates a strong level of correlation. The weights are summed by column, and the weight percentage of each column is calculated to rank which engineering characteristic is the most important for the project. This process allows the group to quantitatively determine which engineering characteristics best satisfy the customer's needs and eliminate characteristics that hold little weight over the project. Figure 9 shows the team's house of quality.

		Engineering Characteristics									
Improvement Direction		↑	↓	↑	=	=	↑	↓	↓	↑	↓
	Units	J/min	TB	Cycles	N/A	N/A	kg	kg	Mpa	HP	deg
Customer Requirements		Store Power	Store Data	Endure Fatigue Stress	Regulate Drag	Control Lift	Increase Buoyancy	Decrease Buoyancy	Withstand Pressure	Generate Forward Thust	Control Orientation
1. Waterproof	4			3					9		
2. Versatility of Environment	1								9		
3. Path Optimization	5	1			3	3	9	9		3	9
4. Center of Pressure Tracked	3	3	9		9	9					9
5. Motion of Glider Tracked	4	3	9							3	9
6. Withstand Pressure	7	9		9					9		
7. Depth	4	1		3	9	9	9	9	3	1	
8. Simulation	7				1	1	1	1		1	1
9. Track Temperature of Environemnt	1	3	9								
Raw score		96	72	87	85	85	88	88	120	38	115
Relative weight %		0.1098	0.0824	0.0995	0.0973	0.0973	0.1007	0.1007	0.1373	0.0435	0.1316
Rank Order		3	9	8	7	6	4	5	1	10	2

Figure 9: House of Quality

From the House of Quality, the most important engineering characteristic was determined to be “Withstand Pressure”, and the least important characteristic was determined to be “Generate Forward Thrust”. Although the latter was off from the next lowest concept by 0.0389, the general deviation was not enough for the group to concretely eliminate the characteristic.

1.6.3 Pugh Charts

To help the team identify which design concept is the best compared to the alternatives, the relative comparison technique known as a Pugh Chart was used. The Pugh chart allows the team to analyze the most crucial engineering characteristics and compare them against other design concepts. The concepts used in the Pugh charts are the selected medium and high-fidelity concepts from the generation phase. The Pugh chart is set up with the leftmost column being the selected datum concept, which is compared to the concepts occupying the left onward of the datum column, and the top row providing the engineering characteristics. Each comparison will be given a “+”, “- “, or “=”, as a way to assign whether the compared concept is better (“+”), worse (“-“), or equal (“=”) to the datum. Each element is then summed at the bottom to show the results of the comparison.

Concepts								
Selection Criteria	Datum	1	2	3	4	5	6	7
Store Power	Boeing Wave Glider	-	=	-	-	-	+	+
Store Data		-	-	-	-	-	-	-
Endure Fatigue Stress		+	+	-	-	-	-	-
Regulate Drag		+	+	-	-	-	-	+
Control Lift		+	+	+	+	+	+	+
Increase Buoyancy		+	+	+	+	+	+	+
Decrease Buoyancy		+	+	+	+	+	+	+
Withstand Pressure		+	+	+	+	-	=	+
Generate Forward Thust		+	+	+	+	+	=	-
Control Orientation		+	+	+	-	=	-	-
# Of Pluses		8	8	6	5	4	4	6
# Of Minuses		1	1	4	5	5	4	4

1	Adjustable Wing	
2	Dual Hull	
3	Piston Excavated Buoyancy	
4	Helicopter Glider	
5	Electromagnetic Pump Glider	
6	Jellyfish Glider	
7	Harvesting Glider	

High Fidelity
Medium Fidelity
Boeing Wave Glider
Eliminated

Figure 10: Pugh Chart 1

From Pugh Chart 1, the concepts which compared the best against the Boeing Wave Glider were found to be the Adjustable Wing, Dual Hull, Piston Excavated Buoyancy, and Harvesting Glider concepts. The three concepts that were eliminated were the Helicopter Glider, Electromagnetic Pump Glider, and Jellyfish Glider. Concepts were eliminated because they were either average compared to the datum concept or worse than the datum concept.

Concepts					
Selection Criteria	Datum	1	2	3	7
Store Power	Electromagnetic Pump Glider	-	+	-	+
Store Data		+	+	=	=
Endure Fatigue Stress		+	+	=	+
Regulate Drag		+	+	=	+
Control Lift		+	+	+	+
Increase Buoyancy		+	+	+	+
Decrease Buoyancy		+	+	+	+
Withstand Pressure		=	+	=	=
Generate Forward Thust		-	-	=	-
Control Orientation		+	+	=	-
# Of Pluses		7	9	3	6
# Of Minuses		2	1	1	2

1	Adjustable Wing	
2	Dual Hull	
3	Piston Excavated Buoyancy	Eliminated
7	Harvesting Glider	
5	Electromagnetic Pump Glider	DATUM

Selected Concepts:	
1	Adjustable Wing
2	Dual Hull
4	Harvesting Glider

Eliminated

Figure 11: Pugh Chart 2

The second Pugh chart assisted the team in further refining the ideas. The team chose the Electromagnetic Pump Glider to be the datum for the second Pugh chart. The datum was selected as it had the most average ranking in chart 1. It was chosen in place of the Helicopter Glider due to a higher frequency of equal signs in the rankings.

From our Pugh chart, the Piston Excavated Buoyancy Glider was eliminated due to having the greatest number of minuses. The Adjustable Wing, Dual Hull, and Harvesting Glider were kept due to their number of pluses being greater compared to the Buoyancy Glider.

1.6.4 Analytical Hierarchy Process

The purpose of the AHP process is to compare the magnitude of importance between two different design criteria. This process allows the team to quantitatively evaluate design criteria and decide which design characteristics to prioritize. The ratings given are odd numbers one through nine. One represents equal importance between design characteristics and nine represents much greater importance of the design characteristic from the row as opposed to the characteristic from the column.

Once the pairwise matrix is established and each rating is given, the table is normalized. Each row is averaged to calculate the relative weight of the design characteristic. The equation $\{Ws\} = [C]\{W\}$ is used to create a weighted sum vector, where [C] represents the original pairwise matrix and {W} is the relative weight vector. From this, the consistency vector is calculated with the equation $\{Cons\} = \{Ws\}./\{W\}$. The consistency vector is averaged to get λ and the equation $CI = \frac{\lambda - n}{n-1}$ is used to calculate the consistency index, where n is the amount of engineering characteristics in the binary pairwise table. Finally, the consistency ratio (CR) is calculated with the equation $CR = \frac{CI}{RI}$, where RI is the random index value gathered from

Figure 12. If CR < 0.10, the team can be confident that each rating was given to each engineering characteristic with minimal inherent bias and is a good comparison.

RI Values for Consistency Check

# of Criteria	RI Value
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.4
9	1.45
10	1.49
11	1.51
12	1.54
13	1.56
14	1.57
15	1.58

Figure 12: Random Index Value Lookup Table

	Criteria Comparison Matrix[C]								
	1	2	3	4	5	6	7	8	9
1) Waterproof	1.000	9.000	9.000	5.000	3.000	1.000	1.000	1.000	3.000
2) Versatility of Environment	0.111	1.000	1.000	0.200	0.333	0.111	0.111	0.111	0.200
3) Path Optimization	0.111	1.000	1.000	0.200	0.333	0.111	0.111	0.111	0.200
4) Center of Pressure Tracked	0.200	5.000	5.000	1.000	0.333	0.200	0.200	0.200	3.000
5) Motion of Glider Tracked	0.333	3.000	3.000	3.000	1.000	0.200	0.200	0.200	1.000
6) Survivability	1.000	9.000	9.000	5.000	5.000	1.000	1.000	1.000	3.000
7) Simulation	1.000	9.000	9.000	5.000	5.000	1.000	1.000	1.000	3.000
8) Depth	1.000	9.000	9.000	5.000	5.000	1.000	1.000	1.000	3.000
9) Track Temperature of Environment	0.333	5.000	5.000	0.333	1.000	0.333	0.333	0.333	1.000
Sum	5.089	51.000	51.000	24.733	21.000	4.956	4.956	4.956	17.400
Average	0.565	5.667	5.667	2.748	2.333	0.551	0.551	0.551	1.933

Figure 13: Criteria Comparison Matrix

From the criteria comparison matrix in Figure 13, the λ, CI, and CR values were calculated. Figure 14 shows the consistency check process previously mentioned. The consistency ratio was found to be $CR = 0.050$ which is within the allotted limit and means the rating of engineering characteristics was ranked in an unbiased and consistent manner.

	Consistency Check		
	{Ws}=[C]{W}	{W}	Cons = {Ws}./{W}
	Weighted Sum Vector	Criteria Weights	Consistency Vector
Waterproof	1.798	0.186	9.679
Versatility of Environment	0.168	0.018	9.237
Path Optimization	0.168	0.018	9.237
Center of Pressure Tracked	0.616	0.065	9.468
Motion of Glider Tracked	0.608	0.059	10.306
Survivability	1.916	0.196	9.758
Simulation	1.916	0.196	9.758
Depth	1.916	0.196	9.758
Track Temperature of Environment	0.586	0.065	9.056
		λ =	9.584
		CI =	0.073
		CR =	0.050

Figure 14: Consistency Check Table

The second portion of the AHP process is designed to finally select the best concept. Through PI charts the team compared each concept to an individual design characteristic. The values were normalized and summed. The equation $AV = [FRM]^T .* \{Pi\}$ was used to calculate the alternative value, AV, from the final rating matrix (FRM) and the PI values. The highest AV number was selected as the final concept. Figure 15 shows an example of the PI matrix, Figure 16 shows the final rating matrix, and Figure 16 shows the alternative value matrix the team generated.

[C] Matrix for Store Power					
AHP		A	A	A	
	Concepts	Con. 1	Con. 2	Con. 7	Average
B	Con. 1	1.000	0.200	0.111	0.437
B	Con. 2	5.000	1.000	0.111	2.037
B	Con. 7	9.000	9.000	1.000	6.333
	Sum	15.000	10.200	1.222	
	Average	5.000	3.400	0.407	

Figure 15: PI Matrix

	PI Matrix	A	A	A
B	Engineering Characteristic	Con. 1	Con. 2	Conc. 4
B	Store Power	0.059	0.174	0.767
B	Store Data	0.143	0.143	0.714
B	Endure Fatigue Stress	0.281	0.658	0.061
B	Regulate Drag	0.316	0.632	0.052
B	Control Lift	0.316	0.632	0.052
B	Increase Buoyancy	0.474	0.474	0.053
B	Decrease Buoyancy	0.474	0.474	0.053
B	Withstand Pressure	0.333	0.333	0.333
B	Generate Forward Thust	0.685	0.263	0.052
B	Control Orientation	0.263	0.052	0.000
	Sum	3.284	3.661	1.370

Figure 16: Final Rating Matrix

Concept	Alternative Value
Con.1	0.354
Con. 2	0.394
Con. 7	0.253

Figure 17: Alternative Value Matrix

1.6.5 Final Selection

Viewing the results from house of quality, Pugh chart, and the analytical hierarchy process, the final selection was chosen to be concept 2, the dual hull glider. This was chosen for its ability to meet the customer's requirements while fulfilling all engineering characteristics.

This glider has a distinct advantage over the other concepts for a few reasons. First the glider is operating with a dual piston excavated cylinder. This allows for more control of the buoyancy at two locations away from the center of pressure. Having the ability to adjust buoyancy of one side of the glider can induce roll which will help with maintaining the correct orientation. The dual hull also allows for more room for electronics to be stored ensuring all components needed for operation can be housed safely. With the added control in the vertical direction and roll, the glider no longer needs a tail to adjust for yaw, thus drag will be reduced making the glider more efficient. This glider will be hydrodynamic and highly controllable, making for the best solution when faced with complex oceanic currents over long distances.

Figure 18 shows a preliminary CAD prototype which could be implemented.

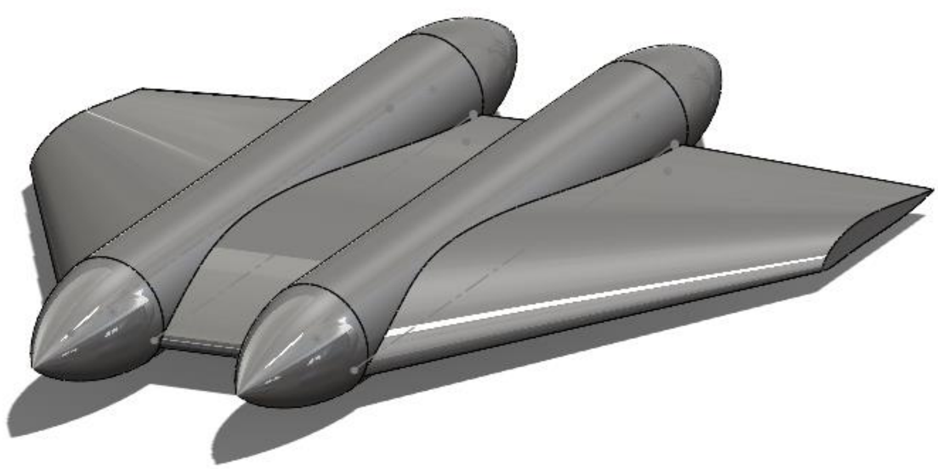

Figure 18: Potential CAD Design of Selected Concept