1.6 Concept Selection

House of Quality

The house of quality is a concept selection technique that allows a quantitative comparison to be made between the engineering characteristics determined in our targets and the needs identified by the customer. A value of 1, 3, or 9 is assigned to a given engineering characteristic, multiplied by the importance weight factor of the corresponding customer requirement, and summed together to provide a score for each engineering characteristic's impact. The target value above the raw score section has no implication on the score but is there for reference.

Table 5: House of Quality

		Engineering Characteristics							
Improvement Direction		↓	↑	↑	↓	↓	↑		↑
Units		m/s	cm2	cm^3	kg	m/s^2	s	m/s^2	N
Customer Requirements	**Importance Weight Factor**	**Impact Velocity**	**Cross-sectional Area**	**Payload Volume**	**Mass of System**	**Microgravity Quality**	**Microgravity Duration**	**Vehicle Acceleration**	**Maximum Supplied Thrust**
Safe Landing	**3**	9			1				
Counteracts Air Resistance	**5**	1	3		3	3	3	3	9
Fits Payload	**2**		9	9		3			
Can Be Lifted by Drone	**1**		1	1	9				
Achieves Microgravity	**3**					9	9	9	3
Aerodynamic Body	**5**	1	3	1		1	1		
Air Vehicle Accelerates	**5**	1	1		3	3	3	9	9
Target Value		1	490	10x10x30	15	10^{-6} G	4	9.81	46.2
Raw Score (478)		42	54	24	42	68	62	87	99
Relative Weight %		8.79	11.30	5.02	8.79	14.23	12.97	18.2	20.71
Rank Order		7	5	8	6	3	4	2	1

The importance of each of the customer requirements was quantized using a binary pairwise comparison, found in appendix D. These are seen in the house of quality next to the customer needs. The most important customer requirements identified were the design's ability to counteract air resistance, be aerodynamic, and accelerate. This is logical, as these qualities will allow for a successful microgravity simulation. The least important needs were the ability of the air vehicle to be lifted by the drone and to fit the payload. While this is mandatory for our design's ability to compete, it is deemed relatively unimportant as a customer requirement due to its lack of implication on other customer needs.

In accordance with the importance weight factors of the customer requirements, each engineering characteristic was ranked in order of importance. The maximization of thrust was found to be the most important and the volume of the payload is the least. This reflects largely on the necessity of achieving microgravity, as thrust will allow for the negation of air friction, thus extending microgravity duration. The larger the thrust supplied, the more the drag force can be counteracted, and a longer microgravity event can be supplied.

Pugh Chart

Pugh charts determine which concepts best accomplish a selection criterion chosen based on the customer needs. The purpose of this exercise is to compare the three high fidelity concepts and the five medium fidelity concepts to a previous design's data. If the concept accomplishes a criterion better than the datum, the concept receives a "+" in the corresponding box. If the concept can't fulfill the criterion better than the datum it receives a " – ", and if it does a similar job to the datum, it receives an "S". The concepts with the most pluses carry on to the next chart, while the concepts with the most negatives are eliminated. The concept with a similar number of pluses, minuses, and S's is selected as the datum for the next iteration. For clarification, each concept was given a nickname associated with the concept's identifying qualities. The nicknames are associated with the medium and high fidelity concepts.

Table 6: Pugh Chart First Iteration

Selection Criteria	**Datum**	Carbon Fiber Missile	Nylon Bullet	Spinning Toothpick	Suction Cups	Fiberglass Bullet	Tornado	Raindrop	Smooth Steel
Parachute Deployment System	**Previous Most Successful Competitor: Gold Team**	+	+	+	+	+	+	+	+
Cross-Sectional Area		+	+	+	S	-	S	-	S
Fits Payload		S	S	S	S	S	-	S	S
Lightweight		+	+	S	+	+	+	-	-
Microgravity Quality		+	+	+	-	S	-	-	S
Thruster System		+	+	+	+	+	S	+	+
Number of +'s		5	5	4	3	3	2	2	2
Number of -'s		0	0	0	1	1	2	3	1
Number of S's		1	1	2	2	2	2	1	3

From the first Pugh chart, in Table 6, two medium fidelity concepts were eliminated: the "Smooth Steel" and the "Raindrop" concepts. The Smooth Steel concept was eliminated with a low number of pluses and a high number of S's, Raindrop also had a low number of pluses, with a high number of minuses. Although "Tornado" had a low number of pluses, it wasn't eliminated equal number of pluses, minuses, and S's.

Table 7: Pugh Chart Final Iteration

Selection Criteria	**Datum**	Carbon Fiber Missile	Nylon Bullet
Parachute Deployment System	**Spinning Toothpick**	+	-
Cross-Sectional Area		-	-
Fits Payload		S	S
Lightweight		+	+
Microgravity Quality		+	+
Thruster System		+	-
Number of +'s		4	2
Number of -'s		1	3
Number of S's		1	1

Two more Pugh chart iterations were created as well. In the second iteration, shown in appendix D, two more concepts were eliminated: “Suction Cups” and “Fiberglass Bullet”. The final Pugh chart, shown in Table 7 above, uses the datum of the “Spinning Toothpick” because of its high comparability criteria. The “Carbon Fiber Missile” was the most successful in this comparison due to its high number of pluses. It had the largest number of pluses in every iteration of the Pugh chart, proving it is the most viable concept; although, the “Nylon Bullet” and the “Spinning Toothpick” are viable concepts as well.

Analytical Hierarchy Process

The analytical hierarchy process (AHP) is an analytical approach to concept selection. It takes the engineering criteria found in the house of quality and compares them to each other, assigning them a number corresponding to their comparative importance. After the initial comparison matrix is complete, it is normalized and the criterion weights for each are found, shown in Table 8 below. These criteria weights are used to identify the importance of each engineering criterion. The same process is repeated but instead high-fidelity concepts are compared based upon each engineering criterion. The final outcome of this process is the alternative values, Table 10.

Table 8: AHP Normalized Criteria Comparison Matrix

	Normalized Criteria Comparison Matrix [NormC]							
	Impact Velocity	Cross-Sectional Area	Payload Volume	Mass of System	Microgravity Quality	Air Vehicle Accelerates	Max Supplied Thrust	Criteria Weights {W}
Impact Velocity	0.087	0.120	0.200	0.055	0.151	0.049	0.107	0.110
Cross-Sectional Area	0.029	0.040	0.040	0.018	0.022	0.082	0.046	0.038
Payload Volume	0.017	0.040	0.040	0.055	0.050	0.049	0.036	0.042
Mass of System	0.087	0.120	0.040	0.055	0.022	0.082	0.064	0.067
Microgravity Quality	0.087	0.280	0.120	0.382	0.151	0.246	0.107	0.211
Air Vehicle Accelerates	0.434	0.120	0.200	0.164	0.151	0.246	0.320	0.219
Max Supplied Thrust	0.260	0.280	0.360	0.273	0.453	0.246	0.320	0.312
Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 9: Final AHP Rating Matrix

Final Rating Matrix			
Selection Criteria	Carbon Fiber Missle	Spinning Bullet	Nylon Bullet
Impact Velocity	0.480	0.115	0.405
Cross-Sectional Area	0.487	0.078	0.435
Payload Volume	0.243	0.088	0.669
Mass of System	0.655	0.187	0.158
Microgravity Quality	0.316	0.052	0.632
Air Vehicle Accelerate	0.480	0.115	0.405
Max Supplied Thrust	0.724	0.193	0.083

Table 10: Alternative Values

Concept	Alternative Value
Carbon Fiber Missle	0.523
Spinning Bullet	0.128
Nylon Bullet	0.348

The “Carbon Fiber Missile” is the concept that has the highest alternative value, meaning that it was determined to be the best concept based on the analytical hierarchy process. In order to make sure there were no biases or inconsistencies, a consistency ratio (CR) was checked for each AHP comparison matrix. It was necessary for each value to be less than 0.10 for this process to be accurate. These values are located, along with the rest of the AHP charts, in Appendix D.

Final Selection

The final selection, based on the steps taken above, is the “Carbon Fiber Missile”. This concept consists of a carbon fiber body that will be formed with a 3D-printed mold, resembling a missile with fins on the tail end for flight stability. The payload will be secured with an internal track system and the parachute will be deployed with a spring-loaded release. The system will be controlled by a Teensy microcontroller and thrust will be achieved with compressed air, the vehicle is also described in Table 4, Concept 1. This concept was one of 100 concepts generated and was selected using the House of Quality (Table 5), Pugh charts (Tables 6, 7, and D-2), and AHP (Tables 8, 9, and D-3 through D-34).