Helium Micro Air Vehicle (MAV)

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Concept Generation and Selection

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1 Introduction

1.1 Introduction

Dr. Srinivas Kosaraju requested to design a Helium Micro Air Vehicle (MAV). The Helium HAV is a device that flies over fires and contaminated areas to take images. There are constraints that will be considered in the Helium MAV project. Such as; the budget should not be more $2000, and the maximum size must be 1.83 X 0.91 X 0.91 m^3. Also the remote control guidance system is one of the constraints and last, we must reaching an altitude of 30.5 m. The objectives of Helium MAV are how to optimize weight and payload, minimize the response time and double the distance of quadcopters. In addition, Helium MAV should be more durable than any commercial product in the market.

The functional diagram will show how the MAV will operate and what operations are needed, with this a set of criteria's were made. A relative weight criteria matrix will compare and contrast the different criteria's and show which specific sub-functions are most important. Based on the relative weights we came up with different concepts and decision matrices. These compare general types of products and which ones we are considering to use, also why we are not using certain ones. Additionally this report will have an updated project plan that will show what we have already completed and what upcoming tasks we need to start on.

2 Functional Diagram

In this Functional Model, the sub-functions were identified and detailed to further explain the flow of our inputs to the outputs (based on Quality Functional Deployment) of the product. The four inputs are: electricity, hand, kinetic energy, potential energy, and weight. By following the outline and multiple processes of each input the following outputs are produced: visual/auditory, sound, heat, torque, hand, and weight.

2.1 Functional Diagram Figure

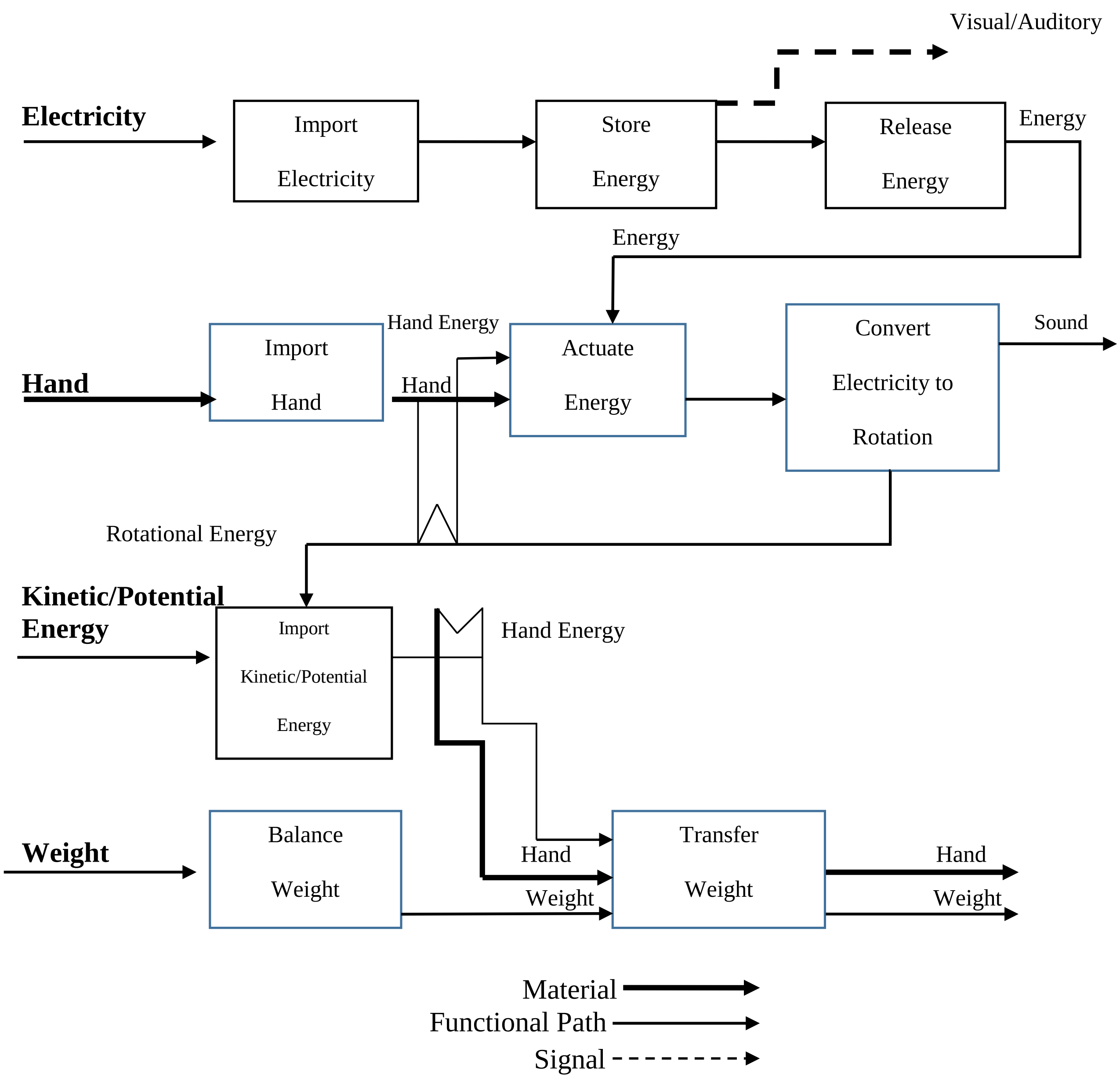

Figure 1: Functional Model

2.1.1 Functional Model Explanation

The electricity in the diagram shows the steps needed to actuate the Helium MAV. First, importing electricity is by attaching the lithium polymer battery to the bottom of the device. We will attach as many batteries as needed to start the device and allow it to fly and power other external systems. Second, storing energy is by placing the batteries and not actuating until command is given. Third, releasing energy is when the person controlling the Helium MAV gives the commands and starting to send power to the motors. With this action we allow visual and auditory to be activated.

The Hand is to operate the remote control to allow the Helium MAV be controlled and monitored. Actuating energy is to switch on the Helium MAV and allowing the Helium MAV to fly. When the switch is on we will convert the energy to rotational energy due to the propellers.

Kinetic energy is the energy that allows the body to accelerate and move forward and back. This energy is to allow the Helium MAV to move and fly around contaminated areas. Potential energy is the energy that allows Helium Mav to hover over and being able to monitor the contaminated areas.

The weight is divided into categories in the project. We as a group will balance the weight and make the flight of the Helium MAV easy and smooth. This will help keep the MAV stable and level. When attaching the components the transfer weight will help to distribute all the components weight equally keeping the MAV balanced.

By creating this functional model, the basis of the product is much better understood, which now lead to possibilities in upgrading and/or changing certain components of the product so that it may function at its best potential. Since the functional model clearly defines the four sub-functions, each member of the team is now also capable of understanding these systems of flow, so that multiple ideas may be produced to further come to a conclusive final product.

3 Criteria

As Demonstrated in the functional model, the sub-functions are gathered and divided as follows, frame, battery, GPS sensor, motor, balloon envelope and camera. These sub-functions are then divided to demonstrate and measure the relative weights of each sub-function.
The frame for example is divided to a) weight, b) volume and c) cost. When dividing the frame into these categories to measure the relative weights each student had to make a table categorize and take the ranking for each of the functions. Each student made the ranking and then we as a group gathered and took the average of all the rankings made.

Table 1: Criteria for Helium MAV

Frame	GPS/Sensors	Motor	Batteries	Balloon Envelope	Camera
Weight	Controllable	Weight	Life	Payload	Size
Volume	Pre-Programmable	Thrust	Amps	Volume	Cost
Cost	Range	Cost	Voltage	Cost	Weight
X	Wi-Fi	Batteries Capability	Weight	Material	Resolution
X	Cost	X	Cost	Shape	Waterproof

4 Relative Weights of Criteria

The Relative weights of this project consist of six categories, frame, battery, GPS/sensor, motor, balloon envelope and camera. These categories are gathered from the functional model as well as the QFD. These tables are the averages of the entire group.

4.1 Frame

The frame is divided to a) weight, b) volume and c) cost. When dividing the frame into these categories to measure the relative weights each student had to make a table categorize and take the ranking for each of the functions. Each student made the ranking and then we as a group gathered and took the average of all the rankings made.

Table 2: Frame

Frame		
Criteria	Relative Weight	Percentage
Weight	0.533	53.3%
Volume	0.338	33.8%
Cost	0.129	12.9%

4.2 Battery

The battery is divided to a) life, b) amps, c) voltage, d) weight and e) cost. When dividing the battery into these categories to measure the relative weights each student had to make a table categorize and take the ranking for each of the functions. Each student made the ranking and then we as a group gathered and took the average of all the rankings made.

Table 3: Battery

Batteries		
Criteria	Relative Weight	Percentage
Life	0.244	24.4%
Amps	0.191	19.1%
Voltage	0.284	28.4%
Weight	0.147	14.7%
Cost	0.134	13.4%

4.3 GPS/ Sensor

The GPS sensor is divided to a) controllable, b) pre-programmed, c) range, d) Wi-Fi and e) cost. When dividing the GPS sensor into these categories to measure the relative weights each student had to make a table categorize and take the ranking for each of the functions. Each student made the ranking and then we as a group gathered and took the average of all the rankings made.

Table 4: GPS/Sensor

GPS/Sensors		
Criteria	Relative Weight	Percentage
Controllable	0.269	26.9%
Pre-Programmable	0.204	20.4%
Range	0.124	12.4%
Wi-Fi	0.178	17.8%
Cost	0.225	22.5%

4.4 Motor

The motor is divided to a) weight, b) thrust, c) battery compatibility and d) cost. When dividing the motor into these categories to measure the relative weights each student had to make a table categorize and take the ranking for each of the functions. Each student made the ranking and then we as a group gathered and took the average of all the rankings made.

Table 5: Motor

Motor		
Criteria	Relative Weight	Percentage
Weight	0.342	34.2%
Thrust	0.290	29.0%
Cost	0.213	21.3%
Battery Capability	0.155	15.5%

4.5 Balloon Envelope

The balloon envelope is divided to a) payload, b) balloon material, c) volume, d) shape and e) cost. When dividing the balloon envelope into these categories to measure the relative weights each student had to make a table categorize and take the ranking for each of the functions. Each student made the ranking and then we as a group gathered and took the average of all the rankings made.

Table 6: Balloon Envelope

Balloon Envelope		
Criteria	Relative Weight	Percentage
Payload	0.262	26.2%
Volume	0.184	18.4%
Cost	0.193	19.3%
Material	0.229	22.9%
Shape	0.133	13.3%

4.6 Camera

The camera is divided to a) size, b) weight, c) resolution, d) waterproof and e) cost. When dividing the camera into these categories to measure the relative weights each student had to make a table categorize and take the ranking for each of the functions. Each student made the ranking and then we as a group gathered and took the average of all the rankings made.

Table 7: Camera

Camera		
Criteria	Relative Weight	Percentage
Size	0.250	25.0%
Cost	0.110	11.0%
Weight	0.208	20.8%
Resolution	0.277	27.7%
Waterproof	0.155	15.5%

5 Concept Generation

This section describes the different concepts made for this project. The main methods used to generate the sketches were the C-Sketch method and the internet. Each method obtained different results but were primarily based upon the customer needs. An example from each method is shown below.

5.1 Frame/ Envelope Concepts

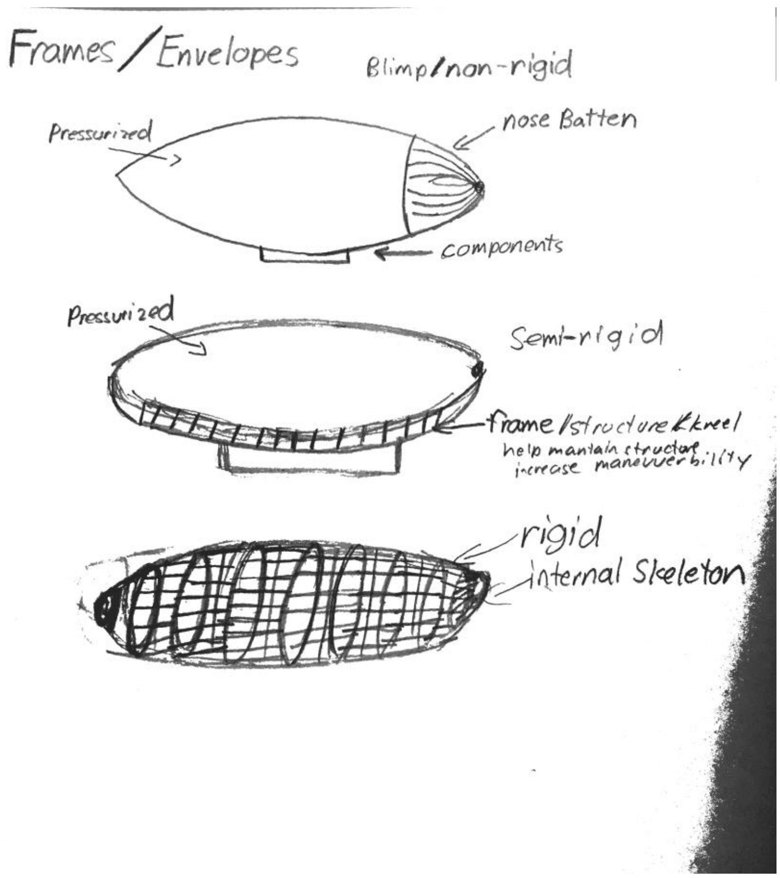

Figure 2: Frames/ Envelopes

5.2 Donut

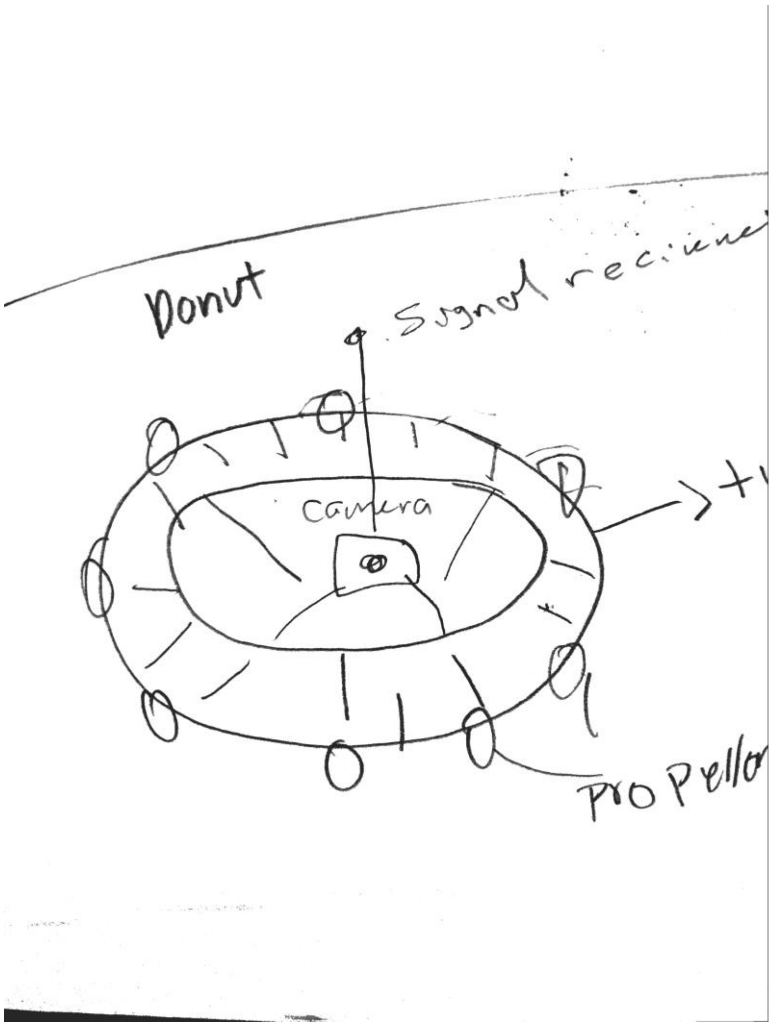

Figure 3: Donut

5.3 Helium Balloon

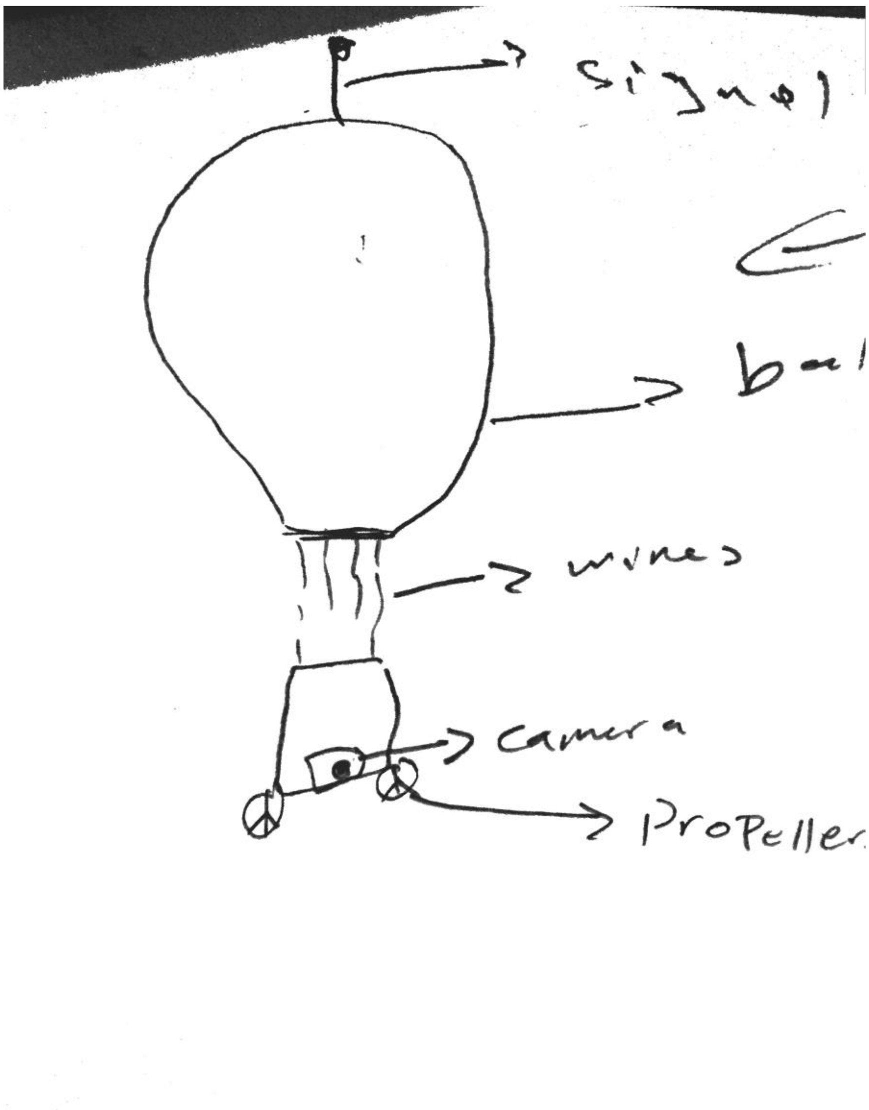

Figure 4: Helium Balloon

5.4 Camera

Figure 5: Canon shot A2300

Figure 6: GoPro Hero4 Black 4K

Figure 7: Sony Cyber Shot

Figure 8: Bell + Howell Splash

5.5 Battery

Figure 9: Lithium Polymer New Tunigy

Figure 10: Turnigy Nano Lithium Polymer

Figure 11: Tenergy Lithium Ion

5.6 GPS

Figure 12: Hardwired GPS Tracking Device

Figure 13: GPS Logger

Figure 14: Personal GPS Tracker

Figure 15: Real Time GPS Tracker

6 Decision Matrix

The Decision Matrix is a tool we used to decide what products are best for specific functionalities of our design. Criteria have been established and relative weights generated for these specific functions by referencing their importance with one another. This part of the report outlines the use of the decision matrices in our product design.

6.1 Frame

We came up with 3 different frames based off of blimps and Zeppelins, semi-rigid, non-rigid, and rigid structures. A non-rigid has no internal structure and keeps its shape by pressure built up within the envelope so when a non-rigid structure deflates it loses its shape. This is important since our client want to be able to store the MAV. A semi-rigid structure is like a blimp in which the shape is formed from pressure so it can be deflated but has a small structure usually aligned at the bottom inside or outside the envelope, which stabilizes, allows for more weight to be distributed, and improves maneuverability. The rigid structure has a full frame so it doesn't lose its shape when deflated and has helium bags instead of just helium. The disadvantage for the frame adds a lot of extra weight and will be more expensive since more material must be added, and can't be stored as easily as the non and semi rigid structures.

In the criteria matrix the non-rigid frame was the best but this is debatable. Even though it is best by the criteria's we set the semi rigid is more stable and can maneuver better with only a slight increase in weight and cost. The rigid frame did the worst because of the amount of weight and would cost more.

Table 8: Frame Decision Matrix

	Weighted Scores	Relative Weight	Volume	Weight	Cost
Non-rigid	9.80	0.408	10	9	5
Semi-rigid	8.04	0.365	10	8	4
Rigid	2.93	0.225	5	5	3
Total			25	22	12

6.2 Batteries / Motor

The battery criteria have been ranked by their relative weights. As these decision matrices display visually the most important criteria we have created, the load capacity is a criteria that always will be the forerunner in our team's decisions. We have established that the battery required would generate different loads compared with a motor we would choose to use. Since the motor and battery act as a symbiotic team, we decided the best and lightest motor for the relative cost based on the state of the art market competitors. Then, we compared how well different motors and batteries would act as a compatible part of the entire project.

An example of how the operating capacity of the motor and battery would act in conjunction with each other would be best described with the payload. Basic understanding of how motors work gives us the knowledge that the greater the current requirement, the heavier the battery and greater the load capacity. Sacrificing weight with the ability to generate enough payload capacity is a definite concern for our group. Determining the best combination of battery and motor is crucial for generating an efficient product. Additional concern is that the battery would operate in series with other operable parts of the design, such as the gauges and camera. Our ability to find products that have their own battery life is a decision that relies heavily on the weight of all the combined parts of the project. The gas engine was not considered in the comparisons of the glow and electric brush engines based on the fact that additional weight required (gas) makes this choice so irrelevant compared to other choices. Furthermore, the size and cost alone make this choice irrelevant. The decision matrix tabulates values for the gas engine on the basis that we have done research for this component and considered this option however unlikely the application.

Table 9: Battery Decision Matrix

Battery Criteria	Relative Weights	Turnigy Nano-Tech	Li-Po New Tunigy	Tenergy 11204	Turnigy Nano-Tech Score	Li-Po New Tunigy Score	Tenergy 11204 Score	Turnigy Nano-Tech	Li-Po New Tunigy	Tenergy 11204
Cost	0.134 (13.3%)	$16.43	$31.29	$16.50	8.36	6.871	8.35	1.120	.920	1.118
Voltage (V)	0.284 (28.3%)	7.4	7.4	7.2	7.6	7.6	7.4	2.158	2.158	2.101
Amps (mAh)	0.191 (19.1%)	2	5.0	3.0	4	10	6	.764	1.91	1.146
Weight (g)	0.147 (14.6%)	98	279	314.67	9.925	7.39	7.03	1.458	1.086	1.033
Life at max capacity (mins)	0.244 (24.4%)	60	60	60	=	=	=	2.44	2.44	2.44
Score	**Weighted Scores**				29.885	31.861	28.78	**7.941**	**8.515**	**7.839**

Table 10: Motor Decision Matrix

Motor Criteria	Relative Weights	Donkey ST2204	Scorpion HKII Glow Engine	AXI Gold 2808/24 Outrunner Motor	Gas	Donkey ST2204	Scorpion HKII Glow Engine	AXI Gold 2808/24 Outrunner Motor	Gas	Donkey ST2204	Scorpion HKII Glow Engine	AXI Gold 2808/24 Outrunner Motor
Cost	**.213**	$16.10	79.99	$99.99	127.99	9.195	6	4.99	3.6	1.958535	1.278	1.06287
Load Capacity (g)		440g		595.0 - 1502.0g								
Voltage(V)	**.155**	6-13v	15v	7.2-12v	6v	4.5	10	9.6	2	.6975	1.55	1.488
Amps(A)	**.155**	12A	42A	30A		10	1.6	.4		1.55	.248	.062
Power	**.290**	1700	3000	1190	8800	1.7	3	1.19	8.8	.493	.87	.3451
Weight(g)	**.342**	39g	81g	76.54g	≈ 650g	9.44	8.842	8.906	.714	3.22848	3.023964	3.045852
Score										**7.927515**	**6.969964**	**6.003822**

6.3 GPS

One of the main sub-systems in the Helium MAV is the GPS tracking device, which allows the operator to locate and pinpoint the position of the vehicle even in low visibility environments. As a result, to find the most suitable tracking device for the MAV, four basic types of tracking devices has been considered which are the Hardwired GPS Tracking device, GPS Logger, Personal GPS Tracker and Real-Time GPS Tracker. To have a better understanding, research was made in order for the team to familiarize themselves with these basic types. The Hardwired GPS Tracking device is usually used in cars and most of the time it requires an antenna to operate, it also needs an external battery. The GPS Logger is used to record data and the data can be visible only by uploading it to a computer through a certain software. These type of trackers are used in the post office where customers can check the position of his/her shipments, the GPS logger would show the last station that it was last checked in. Personal GPS trackers are small in size and most of the time comes with a panic button to alert the specialist for an emergency, Personal GPS trackers are used widely by patients and elderly for a safety purposes. A Real-Time GPS tracker is a device that comes in various shapes and has multiple uses, this device can provide a live feed and however, it requires GPS tracking software and the use of tracking services. In comparing these four types of systems, four criteria were chosen which are weight, power source, real time feed and cost. Below are the decision matrices used to compare these four GPS types.

Table 11: GPS Decision Matrix

Criteria	Weight	GPS Logger	Personal GPS Tracker	Real Time GPS Tracker	Hardwired GPS Tracking Device	Hardwired GPS Tracking Device	GPS Logger	Personal GPS Tracker	Real Time GPS Tracker
Weight	0.269	3.54	5.6	8.8	5.72	1.538	0.952	1.506	2.367
Power source	0.178	10	10	10	5	0.89	1.78	1.78	1.78
Real time feed	0.204	5	10	10	10	2.04	1.02	2.04	2.04
Cost	0.225	8.8	4.16	3.36	6.56	1.476	1.98	0.936	0.756
Total	1	27.34	29.76	32.16	27.28	**5.944**	**5.732**	**6.262**	**6.943**

6.4 Sensor

In this section, the sensors will be discussed which in this particular project temperature and wind sensors were used. In the matrix above the Digital Anemometer with Thermometer included was a single item which was able to calculate the wind speed and the temperature and this system is able to calculate these measurements more accurately. On the other hand, the Mechanical Wind Sensor plus Temperature Sensor are two different systems which are compared to the other single system. By using two systems which are mechanical these do not use any power source so it would be easier to operate them. However, the Digital Anemometer with Thermometer included is the better choice because it is more accurate, costs less ad also take up less volume. These systems' details were found through amazon.com.

Table 12: Sensor Decision Matrix

Criteria	Digital Anemometer and Thermometer Included	Mechanical Wind Sensor + Temperature Sensor	Weight	Digital Anemometer and Thermometer Included	Digital Anemometer + Temperature Sensor
Weight	9.06	1.92	.312	2.827	.599
Power Source	5	10	.192	.96	1.92
Cost	10	5	.266	2.66	1.33
Volume	9.11	5.96	.230	2.095	1.371
Total	33.17	22.88	1	**8.542**	**5.22**

6.5 Balloon Envelope

The Balloon envelope is the outside of the MAV that contains the helium. Volume, Material, Amount of weight it can lift (Payload), Shape, if it is aerodynamic or not to improve maneuverability and reduce the drag and cost. Some designs we came up with was the typical blimp, a donut, regular hot air balloon, and multiple envelope design. Each one of these can hold the payload weight and have can hold the same amount of helium so the deciding factor is the cost and shape. We want the balloon to maneuver well so the shape matters and it also determines the amount of drag.

Based on the criteria the basic blimp design is the best but not by much when compared to the donut and the hot air balloon. The reason the multiple one would do so bad is that there would be drag on each envelope and the wind would cause instability and a lot of drag so it wouldn't be as efficient

Table 13: Balloon Envelope Decision Matrix

Balloon Envelopes	Relative Weights	Standard Blimp	Donut	Air balloon	Multi-balloons
Payload	0.274	10	10	10	10
Material	0.192	7	7	7	7
Shape	0.135	7	5	5	3
Volume	0.274	10	10	10	10
Cost	0.122	5	5	5	3
Total		39	37	37	33
Weighted		**8.40**	**8.13**	**8.13**	**7.61**

6.6 Camera

The professional camera is the Canon power Shot A2300 has many specifications. The camera for the Helium MAV such as; size, cost, weight, resolution, and must be waterproof. It is small in size m^3(0.0001020) and could be easily carried onto the MAV as it weighs 127 g. it costs $224 it is cheap for a professional camera. We did not go with this camera as it is not waterproof nor Wi-Fi able so it could not do a live feed of the contaminated areas.

The criteria's for the Digital Sony Cyber Shot are as follows with the size, cost, weight, resolution. This size of this 0.0021609 m^3 which is medium in comparison to the sizes of other cameras. It costs $ 799.99 this price is expensive and due to the ranking and the relative weights it received a very low rank. It weighs 635.029 g that is very heavy and due to the power needed to lift the MAV it will require more power to lift this camera. The resolution of this camera is

20.9 megapixels this camera has a very big resolution. This camera will not work with this project as it does not meet all the specifications.

The disposable Bell + Howell Splash has advantages and disadvantages. The advantages are the light weight as it weighs 0.00206477 m^3 with the film. It has a low cost of $53.63 and the 12 megapixel camera. The disadvantage of this camera it has a heavy weight of 453.592 g and this could interrupt with the weight balance and distribution it also does not have a monitor and could not be connected to a Wi-Fi.

The action camera is important in the Helium Micro Air Vehicle project for taking images over fires and contaminated areas. There are some criteria to choose the best camera for the Helium MAV such as; size, cost, weight, resolution, and must be waterproof. After comparing by using decision matrices with other cameras criteria. The action (GoPro Hero4 Black 4K) camera is the ideal model to use for the project and it costs $499.99. Also, it weighs 81 gram which has the lightest weight. The camera has a resolutions of 12 megapixel. Action (GoPro Hero4 Black 4K) camera is the ideal camera for Helium MAV project due to its specifications. We as a group are searching for similar cameras with lower prices that can offer better quality job to the MAV. We chose in general the action cameras, with comparison to other types of cameras, as it meets all conditions that are specified and wanted for this project. These types of action cameras are available in different brands and we chose the best one in the market to make our preferred model of it.

Table 14: Camera Decision Matrix

Camera Types	Canon power Shot A2300	Action (GoPro Hero4 Black 4K)	Digital (Sony Cyber Shot)	Disposable (Bell + Howell Splash)
Size	2.199	2.472	2.49	2.49
Cost	0.792	1.4125	0.01375E-3	0.4664
Weight	0.358	2.059	0.2329	0.8819
Resolution	3.75	2.49	1.708	1.498
Waterproof	0	0.155	0	0.155
Total	7.038	8.5885	4.4309	5.4913

7 Updated Project Plan

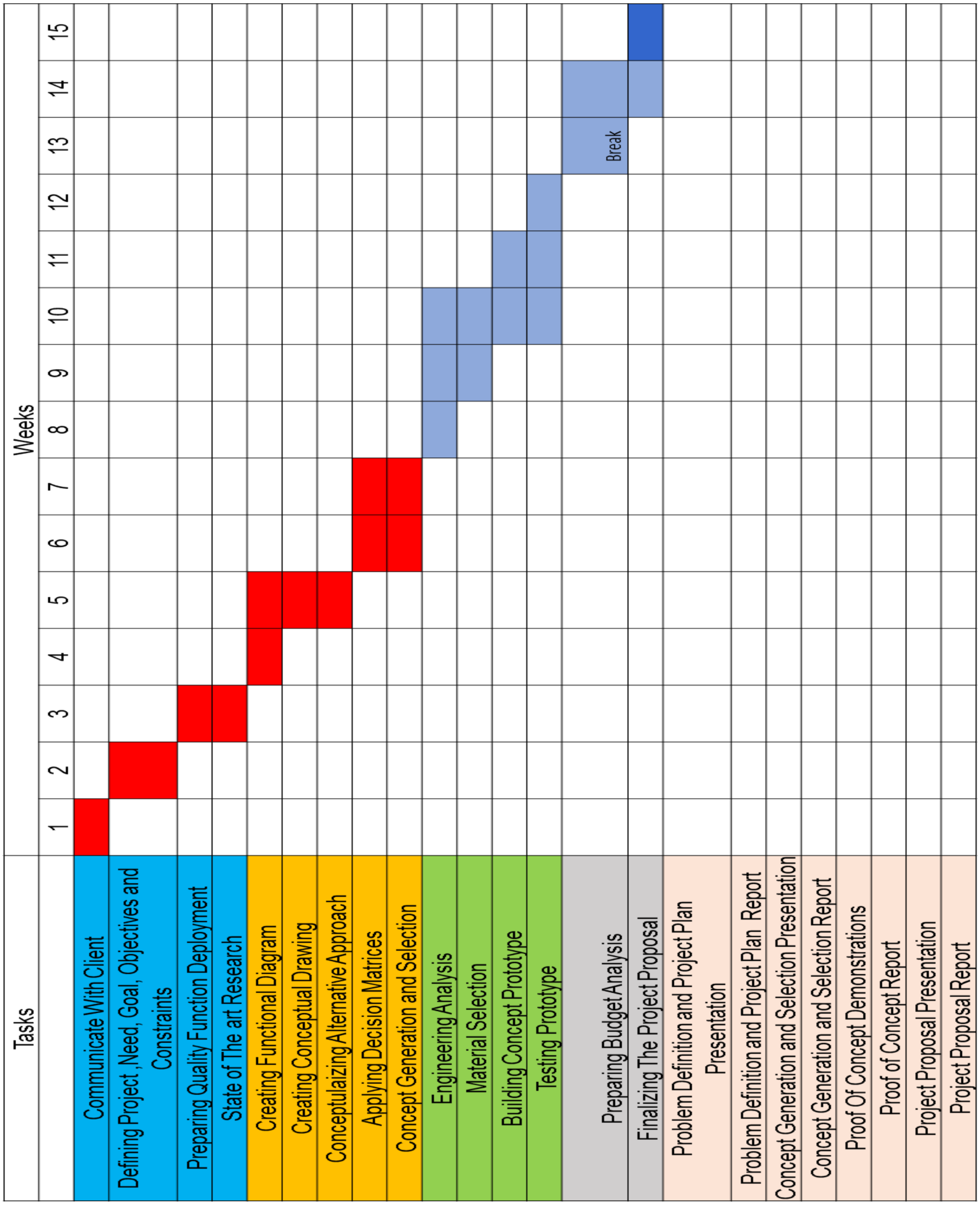

Figure 16: Gantt Chart excerpt for the project. Sections with bars indicate the task has been completed.

The updated project plan of Helium Micro Air Vehicle project shows that we spent 2 weeks, which are week 4-5, to create the function diagram and generated a set of criteria. In week 5 we finished developing conceptual drawings and started on decision matrices. We finished up developing and comparing our decision matrices in week 6 and 7 with the majority of week 7-8 writing the report.

The updated project plan shows when we will finish MAV project. The project plan show that, we have three weeks to build a concept prototype. After that we have to test prototypes to know if it will work. In week 13 we have break then we will start preparing budget analysis in weeks 14. When we finish preparing budget analysis, we will finalize the project proposal in weeks 14 and 15.

8 Conclusion

The concerns we have at this stage in product design rely on what we are expected to generate at the time of the next presentation. The objective now is to be able to find the best possible products under each criteria. These different criteria will all add to the overall weight of the payload, which we will use to calculate a desirable amount of helium based on the volume payload of helium in grams per cubic meter. We will base much of our frame design on this number, considering that the prototype will have to display to the client that we can in fact lift the required amount of weight with the calculated amount of helium. This step is huge when we consider the actual function of the MAV and when we consider identifying an envelope design. Overall, this memo outlines the process in which we chose functional criteria for our design and the best products available on the market that pertain to those criteria. The client has been informed of the progress of this capstone and is aware of timetable estimates for milestones.

References

1. Julie Hirtz, Robert Stone, Daniel McAdams, Simon Szykman, and Kristin Wood. "A Functional Basis for Engineering Design: Reconciling and Evolving Previous Efforts." *Research in Engineering Design*, vol. 13, pg 65-82, March 2002.

2. Dieter, George E & Schmidt, Linda C, Engineering Design, 4th ed., New York City, New York: McGraw-Hill, 2009, ISBN 978-0-07-283703-2.

3. *Barnes C.H. & James D.N. Shorts Aircraft since 1900. London (1989): Putnam. p. 560.ISBN 0-85177-819-4*

4. Dan, Vergano. "100 years in the air." *USA Today* n.d.: *Academic Search Complete*. Web. 23 Oct. 2015 ISSN 0734-7456

5. F. Croce, G. B. Appetecchi, L. Persi and B. Scrosati.Nanocomposite polymer electrolytes for lithium batteries. Nature Publishing Group.Jul 30, 1998.

6. Tracking the world. “Four types of GPS tracking systems”. 1633 Bayshore Hwy Suite 390 Burlingame, CA 94010. Copyright 2015.