1.6 Concept Selection

1.6.1 Movement Hardware and Software Selection

For this module, the focus is to ensure the robot can move quickly while still maintaining stability and control. The frame chosen for this design will have to be lightweight as well as durable and sturdy. 6060 Aluminum was chosen for the frame material due to its relatively inexpensive cost of $2.50 per kilogram and high yield strength of 26,000 psi. The frame will be taking up most of the weight and ensuring it has a lightweight frame is vital in ensuring its speed. For the battery, the Talentcell battery was chosen due to its 6000-amp hour rating and at 20W with 12V operating voltage. The battery was chosen by considering which ones would need the least amount of recharging after use. Also, the overall size pf the battery is beneficial in conserving space. The motor chosen for the design was the CE gear brushless motor. It has a max rpm of 33,000 and an operating voltage of 7.2 V at 4.2 A. The motor would be useful in ensuring the robot is able to reach top speeds quickly.

1.6.1.1 Material Solution Selection

For the material selection, the 6060 Aluminum was chosen on the basis of light density, yield strength, and overall cost. The aluminum has an impressive yield strength of 26,000 psi. The one downside to the aluminum its heavy density of 2.71 g/cm^3. The Aluminum has a low cost of $2.50 per kilogram. Compared to the fiberglass, the aluminum has a more reasonable price range but lacks the light density that is maintained in it. When compared to the hardwood plywood, the wood has a significantly lower yield strength and slightly pricier cost.

	Weight	Baseline	Optimal	Description
Light Density	4	1.5 g/cm^3	1.0 g/m^3	Desired density for lightweight material
Yield Strength	3	15,000 psi	25,000 psi	Overall strength of material
Cost	5	$10.00	$7.50 per sheet	Cost per sheet of material

	Concepts		
Selection of Criteria	Hardwood Plywood	6060 Aluminum	Fiberglass
Light Density	+	-	+
Yield Strength	-	+	+
Cost	-	+	-
Score	-2	4	2

1.6.2.1.2 Battery Solution Selection

For the battery, it was decided that the Talentcell provided the most optimal specifications when considering its compact design, vast amount of amp hours, and wattage. The Talentcell bettery had 6000-amp hours, a compact 1.1 x 3.35 x 5.7 in dimension, and 20 watts. When compared to the HitLights battery, the Talentcell had optimal amp hours but not as much wattage. When compared to the Duracell, the Talentcell had a significantly smaller and more compact design making it useful in the final implementation of the design. Although, the Duracell was able to supply an impressive 8000-amp hours per battery life.

Selection of Criteria	Weight	Baseline	Optimal	Description
Wattage	4	20	30	Overall power supply of the battery
Size	5	2.5 x 2.5 x 2.5	1.0 x 1.0 x 1.0	The dimensions of the battery
Amp Hours	4	4000	6000	Duration of battery life

Selection of Criteria	Concepts		
	HitLights	Talentcell	Duracell Ultra
Wattage	+	0	+
Size	-	+	-
Amp Hours	-	+	+
Score	-5	9	3

1.6.1.3 Motor Solution Selection

When selecting the motor for the final design, it was decided the CE gear brushless motor would be the best based on its optimal operating voltage of 7.2V, high RPM of 33,000, and compact size of 2.0" x 2.0". When compared to the spark fun motor, the CE motor had a significantly higher RPM which would be helpful in attaining high speeds with the robot in a short amount of time and, although the operating voltage of the sparkfun motor is better. When compared to the 8V DC high speed motor, the size of the 8V dc motor was slightly less than the CE motor but its max RPM was slightly less than the CE motor.

Selection of Criteria	Weight	Baseline	Optimal	Description
RPM	5	10,000	30,000	Revolutions per minute of motor
Operating Voltage	4	8 V	7.0 V	Max operating of the motor
Size	3	2.00" x 2.00" X 2.00"	1.5" x 1.5" x 1.5"	Overall Size of motor

Selection of Criteria	Concepts		
	SparkFun Motor	CE gear Brushless Motor	8V DC High Speed Motor
RPM	-	+	+
Operating Voltage	+	+	0
Size	-	0	+
Score	-4	9	8

1.6.2 Route Clearing Algorithm Solution Selection

This selection process will compare the previously discussed methods of route planning and how to best implement them with respect to the qualities desired of the robot. This process will involve defining the qualities desired for the robot to preform competitively at the Southeast Con competition. Then these qualities will be compared to each method and a Pugh Matrix will be used to select the optimal route clearing module.

By using the Pugh Matrix, the concept of predetermined route with debris searching was selected due to its strengths in searching the playing field and avoiding known objects. However, this method only has moderate resistance to environmental noise and is slow at implementing the UFO avoidance code.

1.6.2.1 Route Clearing Algorithm Solution Selection

For the Southeast Con competition an automated robot will be tasked with moving randomly placed debris from a center zone to an outer zone. To do this in under the allotted round time of 3 minutes a robot must be able to efficiently search the playing field for debris. The function of this route clearing algorithm is to find an effective way to quickly search the field and remove debris. The route clearing algorithm will provide the robot with a method of quickly searching the playing field, identifying debris, and avoiding known obstacles. The solution to this selection will possess the following qualities:

- Quickly search the playing field
- Avoid all known objects
- Resistant to environmental noise
- Allow for adjustments to avoid UFOs

To decide which design best fits the requirements for the Southeast Con robot a Pugh Matrix was used. The table below (table 1.6.2.1.1) breaks down the qualities listed above for use in the Pugh Matrix. The weight of each quality was selected on a scale of 1 to 5, with 5 being a critical quality to the overall design of the robot. Each baseline was selected based on the nominal operation of each method. While the optimal is based on the targets previously mentioned.

Table 1.6.2.1.1

Selection Criteria	Weight	Baseline	Optimal	Description
Searching the Playing Field	5	2.5 min	1.5 min	Time to completely search the playing field for debris
Known Object Avoidance	4	3 in	6 in	Smallest distance robot comes to collision with a known obstacle
Resistance to Environmental Noise	2	3 times	0 times	Number of times the robot malfunctions due to environmental noise
Time to Implement UFO Avoidance Code	3	2 sec	< 1 sec	Time for the robot to recognize a UFO and implement UFO avoidance code

Table 1.6.2.1.2 below is the Pugh Matrix to assist with the decision of which route clearing algorithm best fits the Southeast Con robot. The Pugh Matrix is a comparison of each route clearing concept and the qualities desired in the robot to the baseline in table 1.6.2.1.1. The “+” represent an increased performance, “-” represent a decreased performance, and “0” represents no significant difference. The score for each method is the sum of the weight of each quality multiplied by the comparison symbol. For example, the predetermined route is (4+2) + (- 5-3) which results in a score of - 2. The highest scoring concept was a predetermined route with debris searching. This concept allowed for quick searching of the playing field, avoidance of known objects, moderate resistance to environmental noise, and a moderate response time to avoid UFOs.

Table 1.6.2.1.2

Selection of Criteria	Concepts: Predetermined Route	Debris to Debris	Predetermined Route with Debris Searching	Survey and Route Planning
Searching the Playing Field	-	0	+	+
Known Object Avoidance	+	-	+	+
Resistance to Environmental Noise	+	-	0	-
Time to Implement UFO Avoidance Code	-	+	0	-
Score	-2	-3	9	3

1.6.2 Microcontroller Selection

This selection process will compare the previously discussed microcontrollers with the qualities desired to create a competitive robot for Southeast Con. This process will involve defining the qualities desired for the robot to preform competitively. Then these qualities will be compared to each microcontroller in a Pugh Matrix and an optimal microcontroller will be selected.

By using the Pugh Matrix, the microcontrollers Raspberry Pi B+ and BeagleBone Blue were selected. These microcontrollers were both selected because they scored the same in the Pugh Matrix and only have subtle differences between them. The BeagleBone Blue will most likely be used in this robot due to being specifically designed to operate robots.

1.6.2.2 Microcontroller Solution Selection

For the Southeast Con robot to be competitive it needs to be able to make complex decisions. The most efficient and simplest way to accomplish this is using a microcontroller. The microcontroller for this robot will need to have enough processing performance, memory storage, number of pins, and be small enough to fit on the robot. Table 1.6.2.2.1 below breaks down the selection criteria needed to compare each microcontroller in a Pugh Matrix. The table quantifies each selection criteria by weight, baseline value, and optimal value. The weight is a number between 1 and 5 describing the importance of that criteria to the robot's overall performance. Baseline represents the nominal value desired for that criteria, while optimal describes the desired value for competitive performance.

Table 1.6.2.2.1

Selection Criteria	Weight	Baseline	Optimal	Description
Processing Performance	4	180 MHz	1 GHz	The speed of the microcontrollers internal clock
Memory Storage	3	256 KB	512 MB	The memory storage capacity of the microcontroller
Size	2	85 mm	56 mm	The physical size of the microcontroller
Number of Pins	4	40	50	The number of available I/O pins on the microcontroller

Table 1.6.2.2.2 below is the Pugh Matrix to assist with the decision of which microcontroller best fits the Southeast Con robot. The Pugh Matrix is a comparison of each microcontroller and the qualities desired in the robot to the baseline in table 1.6.4.1.1. The "+" represent a improved performance, "-" represent a decreased performance, and "0" represents no significant difference. The score for each method is the sum of the weight of each quality multiplied by the comparison symbol. For example, the Teensy 3.6 is (0+2+4) + (-3) which results in a score of 3. The highest scoring concept was tie between the Raspberry Pi B+ and Beaglebone Blue. These two microcontrollers behave similarly in both processing performance, memory storage, size, and number of pins. A closer inspection of these two microcontrollers show that the Raspberry Pi B+ has a slightly better processer and significantly better storage. However, the BeagleBone Blue has more pins, is slightly smaller, and is specifically designed to be used in robotics.

Table 1.6.2.2.2

Selection of Criteria	Concepts: Raspberry Pi B+	Arduino Mega 2560	Teensy 3.6	BeagleBone Blue
Processing Performance	+	-	0	+
Memory Storage	+	0	-	+
Size	0	-	+	0
Number of Pins	0	+	+	0
Score	7	-2	3	7

1.6.3 Sorting Hardware and Software Solution Selection

In this section the solutions from the concept generation for the sorting hardware and software solution was analyzed. These solutions included gathering, sorting and storage methods, Making the proper selection for this module increases the maximum point for the threshold. However, as each function's solution was selected, power consumption was kept in mind, so this module does not pull to much power from the battery. These solutions were picked based on the most engineering benefit through a Pugh chart and other information that could not have a numerical value.

1.6.3.1 Gathering Solution Selection

During the concept generation phase, several gathering solutions were considered. These solutions were the not gathering space debris, extendable arm system, and the dual brush system. To decide what solution was the best fit for the robot, a Pugh chart was used to assist with decision. Table 1.6.3.11 brakes down the criteria used in the Pugh chart. Maximum possible points was given the highest weight of 5 because this limits the overall points the robot can gathered. 210 points was chosen as the baseline because of target 7, space debris gathered, marginal value was seven space debris gathered. Then assumed that the robot was able to get the space debris out of zone 2 to zone 1, sort all space debris gathered, and then turn them into the proper color coded home. Which is 30 points per space debris, or 210 points for all 7 pieces of space debris. For the optimal value was based on the all available pieces of space debris was properly taken care of, or 360 points. Power consumption was baseline was based on two average stepper motors, because we did not want to draw too much power for the sorting hardware and software module. Gathering time baseline was chosen on if an opponent robot were to take the shortest orbit possible, and was traveling at maximum speed of 4.5 ft/s. which would cause the opponent robot to complete one in about 1.5 seconds. Then this would lead the robot needs to spend five seconds rotating about the shortest orbit to gather same amount of for maximum threshold for points of one piece of space debris. Two seconds was chosen as the optimal value because then the robot gather two pieces of space debris for every five seconds another robot spend rotating, effectively increasing overall possible point threshold for one round.

Table 1.6.3.1.1

	Weight	Baseline	Optimal	Description
Max Possible Points	5	210	360	Enough points to be competitive
Power Consumption	2	100W	60W	Amount of power the solution consumes
Gathering Time	4	5s	2s	Time to gather 1 piece of Space Debris

In table1.6.3.1.2 is Pugh chart for the gathering solution selection. The information gathered in the concept generation was applied to the criteria, then scored to its respective weight. Dual Brush System ended up having the highest score, because it exceed all baselines in this selection. It should be noted that even though the “Don’t Gather Space Debris” solution had four times the maximum points to gathered, the power consumption was high compared to the other solutions, because the need of either more motors or higher quality motors which lead to more power consumption. The final decision is a combination of “Don’t Gather Space Debris” and “Dual Brush System” methods. The idea is while there is space debris is present, the robot will try to focus on gathering space debris. However when the field is void of space debris, the robot will focus on orbits.

Table 1.6.3.1.2

Selection of Criteria	Concepts		
	Don't Gather Space Debris	Extendable Arm System	Dual Brush System
Max Possible Points	+	+	+
Power Consumption	-	0	+
Gathering time	+	-	+
Score	7	1	11

1.6.3.2 Sorting Solution Selection

During the concept generation phase, several sorting solutions were considered. These solutions were the Elevator meets Rubik's cube approach, Lane Driver, and the Linear Memory methods. To decide what solution was the best fit for the robot, a Pugh chart was used to assist with decision. Table 1.6.3.2.1 brakes down the criteria used in the Pugh chart. The sorting time baseline and optimal value was the same as gathering time because as the piece is moving to another space debris or gathering, the robot should have sorted and deposited the recent piece of space debris. The baseline for the working volume was selected to be two pieces of space debris, because that would take up 15% of space on the first level of the robot. This area is valuable for the fact that is where the important components will lived. Anymore space taken up for space prior to sorting is not possible. Little to no space is the target for this criteria. Two motors was selected to be the baseline because to avoid too much power consumption by this module. However at least one motor will be necessary to move the space debris from the gathering module to the sorting module.

Table 1.6.3.2.1

	Weight	Baseline	Optimal	Description
Sorting Time	5	5s	2s	The time to take to sort the space debris
Working Volume	3	2 pieces of space debris	1 pieces of space debris	The space available prior sorted needed
Motors	2	2	1	Amount of motors needed to sort

In Table 1.6.3.2.2 is the Pugh chart for the sorting selection. The information gathered in the concept generation was applied to the criteria, then scored to its respective weight. The Linear Memory solution gather the most amount of points. This method would superior in sorting time due to how simple the process is. Also since the sorting time is so short, the working can be minimal compared to the other ideas. Lastly one motor is need since the sorting method will simply check the color, and drive the space debris straight to the storage chamber. However, the team has decided to go with “Elevator meets Rubik’s cube approach” because the need of a linear storage capacity for the Linear Memory method. The linear storage refers to storage chamber that must keep the space in the same order that it entered so that the robot does not lose track of where it is located. Having the space debris jumbled but color coded allows during the period in which the robot has to deposit the space debris in the proper color coded corner to take up less time. In the linear storage it must rush side to side to place the space debris in the right corner, while the other method only has to do one loop to drop off the space debris.

Table 1.6.3.2.2

	Concepts		
Selection of Criteria	Elevator meets Rubik’s cube approach	Lane Driver	Linear Memory
Sorting Time	-	-	+
Working Volume	+	0	+
Motors	0	-	+
Score	-2	-7	10

1.6.3.3 Storage Solution Selection

During the concept generation phase, several storage solutions were considered. These solutions were the box storage system, simple sack storage and horizontal lane storage system methods. To decide what solution was the best fit for the robot, a Pugh chart was used to assist with decision. Table 1.6.3.3.1 brakes down the criteria used in the Pugh chart. Volume baseline was decided base on the assumption that the team was able to gather all pieces of space debris. Also, the idea that all the space debris were all spheres was assumed because to avoid one getting stuck in the specified chamber. Also, the storage solution must keep all the space debris color coded, it would make the sorting solution pointless and decrease the maximum point threshold.

Table 1.6.3.3.1

	Weight	Baseline	Optimal	Description
Volume (L X W X H)	3	5” X 5” X 6.5”	5” X 5” X 5.25”	Internal volume that the storage unit should hold
Keeps the Space Debris Sorted	5	Yes	---	Keeps the space debris sorted

In Table 1.6.3.3.2 is the Pugh chart for the sorting selection. The information gathered in the concept generation was applied to the criteria, then scored to its respective weight. The boxed storage system solution gathered the most amount of points and will be the team’s choice for storage.

Table 1.6.3.3.2

Selection of Criteria	Concepts		
	Boxed Storage System	Simple Sack Storage	Horizontal Lane Storage System
Volume (L X W X H)	+	+	-
Keeps the Space Debris Sorted	0	-	0
Score	3	-2	-3

1.6.4 Return home algorithm

This is the selection process which will compare the methods of home returning that mentioned before. In this section, several qualities which are required for robot of Southeast Con competition to perform well and score more points will be defined. These all qualities will be discussed and assessed for all four methods of returning home. To find out which method is the best one for our robot to compete and win the competition, a rating mechanism will be established. The method which scores most is the best method for returning home.

By using this mechanism, the method of locate and go is selected as the best method. It is because with this method applied, the robot can be precisely and quickly going back to home and the sensor using for the method is common. However, it could be a little bit difficult to apply this method as it is a combination of two methods.

1.6.4.1 Localization solution

In the concept generation phase, we discussed some solutions for localization. These solutions were Distance from walls measuring, color of spacetel detecting, localize by gyro and code disk and locating and go. To decide which solution to be used for our robot, a Pugh matrix is used to help us. Table 1.6.4.1.1 brake down the criteria used in the Pugh matrix. Each criterion has its weight which represent the importance of the criteria. Estimated time is given a weight of 2 because it is a limited time competition, but after estimated the total time for all modules, we concluded that we may have enough time to do all modules, time is not the thing we worry mostly. Thus, the baseline is decided as 35. Accuracy is the most important quality for this module, thus the weight of accuracy is the highest 5. It is because that if the robot cannot precisely go to the colored corner, we will lose a big amount of points. For possibility of error, it is also given a high weight which is 4 since the error could lead to lose points. The ease of implementation is given the weight of 2 as it could be improved if we take efforts on it. The size of the sensor is given a weight of 2, the baseline is chosen as 3'*3'*3' since the maximum size of the robot is 9'*9'*11', we decide to try to limit the size of each sensor under 1/3 of the size of the robot. The baseline for accuracy and possibility of error is chosen as moderate because if big mistake occurs, we might lose too many points to lose the competition.

Table 1.6.4.1.1

	Weight	Baseline	Optimal	Description
Time estimate	2	35	15	Time for returning home
Accuracy	5	moderate	high	The accuracy of the solution
Ease of implementation	2	moderate	easy	Easy or not easy to implement

Possibility of error	4	moderate	low	The possibility of error of the solution
Size of sensor required	2	3'*3'*3'	none	The size of the sensor of the solution

In table 1.6.4.1.2 is the Pugh chart for the localization solution selection. The information gathered in the concept generation was applied to the criteria, then scored to its weight respectively. Locate and go solution ended up having the highest score since it exceeds most of the baselines in this selection. For the solution with a gyro and code disk, it should be noted that it is even better than locate and go solution in some respects like accuracy and estimated time, however, this solution requires a big assembly of sensors and it is rather difficult to implement. The final decision is locating and go solution. This idea absorbed the advantages of two methods which are distance from wall solution and color of spacetel solution. So, this is a both accuracy and feasible solution

Table 1.6.4.1.1

	Concepts			
Selection of Criteria	Distance from walls	Color of spacetel	With a gyro and code disk	Locate and go
Time estimate	+	+	+	+
Accuracy	0	-	+	+
Ease of implementation	0	+	-	-
Possibility of error	0	-	+	+
Size of sensor required	+	+	-	+
Score	4	-3	9	13

1.6.4.2 Wheels Selection

This selection process will compare the previously discussed wheels with the qualities desired to create a swift robot for Southeast Con. This process will involve defining the qualities desired for selecting wheels. Then these qualities will be compared to each wheel in a Pugh Matrix and a final decision will be made.

By using the Pugh chart, the wheels with medium pressure were selected. This kind of wheels was selected because it scored highest in the Pugh chart. It is not only providing enough friction to the robot but also easy enough to access, further it is also enough to carry the robot.

To win the competition of southeast con which is time-limited, it is important to find a kind of wheels that can provide a big friction value which is good to make the robot move quicker. So, the friction value is chosen as the most important criteria which is given weight of 5. The baseline for the criteria is selected as 0.4 so that our robot can move by the center column while not drifting. The price is given the weight of 3 and the baseline for it is 20 dollars since normal wheels usually are not expensive. The baseline of load is defined as 5 pounds as the weight of the robot we designed so far. The optimal value is chosen in case of that we may add more parts to the robot.

Table 1.6.4.2.1

Selection Criteria	Weight	Baseline	Optimal	Description
price	3	20	10	The total price of the wheels
Friction value	5	0.4	0.6	The friction value between wheels and field
load	2	5pounds	10pounds	The highest load of the wheels
Ease of implementation	2	moderate	easy	Easy or not easy to implement

Table 1.6.4.2.2 below is the Pugh Matrix to assist with the decision of which kind of wheels best fits the Southeast Con robot. The Pugh Matrix is a comparison of each wheels and the qualities desired in the robot to the baseline in table 1.6.4.2.1. The “+” represent a improved performance, “-” represent a decreased performance, and “0” represents no significant difference. The score for each method is the sum of the weight of each quality multiplied by the comparison symbol. For example, the Meconium wheels is (5+2) + (-3+-2) which results in a score of 2. The highest scoring concept was the medium pressure wheels. Though this kind of wheels cannot provide a precise and swift performance as meconium wheels for the robot moving, this kind of wheel is cheap and easy to access and program. The load that the wheels can carry is enough for our robot and it has a high friction value which is conducive for high speed which can make our robot competitive.

Table 1.6.4.2.2

Selection of Criteria	Concepts			
	Airless wheel	High pressure wheels	Medium Pressure wheels	Meconium wheels
price	+	+	+	-
Friction value	-	-	+	+
load	+	+	+	+
Ease of implementation	+	+	+	-
Score	2	2	12	2

1.6.5 UFO Avoidance Algorithm Solution Selection

In this section the solutions from the concept generation for the avoidance algorithm was analyzed. These solutions included avoidance method and sensor solution. Making the proper selection for this module helps avoid the loss of points. However, as each function's solution was selected, power consumption was kept in mind, so this module does not pull too much power from the battery. These solutions were picked based on the most engineering benefit through a Pugh chart and other information that could not have a numerical value.

1.6.5.1 Avoidance Solution Selection

During the concept generation phase, several avoidance solutions were considered. These solutions were the predetermined object size, avoidance percentage and ease of implementation. To decide what solution was the best fit for the robot, a Pugh chart was used to assist with decision. Table 1.6.5.1.1 brakes down the criteria used in the Pugh chart. Time estimation baseline was chosen to be three minutes due to the length of one round. The optimal value for time estimation was selected, so the robot would have completed the setup for avoidance prior the minute used to deposit space debris and return home. The avoidance was selected to be 90% because a large amount of points can be loosed by running into structures and run risk of being disqualified from the tournament. 99% was selected because it is truly impossible to have a design that can avoid another structure 100% of the time. Ease of implementation was selected to be moderate because this module will be the last to be installed into the robot, so it should be able to be applied easily.

Table 1.6.5.1.1

	Weight	Baseline	Optimal	Description
Time Estimation	3	3 mins	2 mins	Internal volume that the storage unit should hold
Avoidance Percentage	5	90%	99%	Odds that the robot will avoid a oncoming structure
Ease of Implementation	2	Moderate	Easy	Installing and modifying the solution to the robot

In Table 1.6.5.1.1 is the Pugh chart for the avoidance solution selection. The information gathered in the concept generation was applied to the criteria, then scored to its respective weight. The stop and scan solution gathered the most amount of points, however It will not be the team's pick. The team will go with a mixture of both other choices because the stop and scan would cause the team to much time while the opponent is gathering points or making orbits. The combination of predetermined object size and surveying field while moving, allows the robot to keep moving to pick up space debris, while prepare for an on coming piece of space debris.

Table 1.6.5.1.2

Selection of Criteria	Concepts		
	Predetermined Object Size	Stop and Scan Surround	Surveying Field While Moving
Time Estimation	0	+	-
Avoidance Percentage	0	+	-
Ease of Implementation	0	+	0
Score	0	10	-7