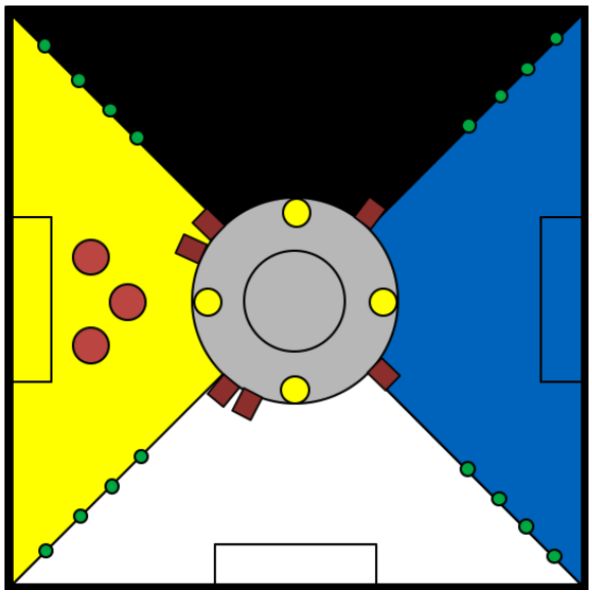
**ME 2110-F**

# Project Planning Report: Mission to Mars



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## I. Abstract

*Creative Decisions and Design*, a Mechanical Engineering class at the Georgia Institute of Technology requires students to compete in a final design competition, in which students team up to design and build an autonomous robot that must complete a variety of tasks in a given amount of time. The creation of the device is limited by budget, energy form, size and dimensions. These restrictions ultimately mean that alternative options for completing each competition task must be explored, and resources must be used wisely and efficiently. Requirements must be met in order to design, assemble and operate a successful robot that will ultimately generate the most points in the final competition based off of each successful task completion. This report explores what the given machine requirements are, different ways to meet these requirements, and planning tools to help prioritize requirements and ensure that the project is utilizing time and resources at maximum efficiency.

## II. Introduction

The ME 2110 "Mission to Mars" final design project presents the challenge of accomplishing multiple tasks with limited space, time and budget. To address these challenges and ensure victory, making a robot is the most feasible option. The robot must complete the following tasks: clear radioactive materials, collect rocks as resources, land spacecrafts in the safe mountain ridges and avoid the dangerous ones, retrieve astronauts and rovers, and place a national flag in the center of the competition track. These tasks must be completed successfully, albeit with many restrictions. The robot must easily clear a 12 x 18 x 24 box, the maximum budget for materials must be below 100 dollars and the robot must successfully carry out these tasks in under 45 seconds. In terms of directly controllable power sources, only pneumatic valves, cylinders, actuators, two motors, two solenoids and five mouse traps can be used total.

Based on these restrictions, it can be inferred that the one of the more difficult challenges will be to choose the correct control signal for each step of the competition. According to the Function Tree in Figure 3, the different steps for each task will be connected by signal inputs and outputs; and, as mechanisms that can generate or receive electronic signals are limited, pure mechanical controls will be crucial. Completing each task with the allotted energy sources is one of the core challenges. Also, as the reliability of some mechanical controllers may not be satisfactory, another important challenge is to decrease the total parts and steps of the functioning machine to reduce the probability of malfunctioning, which can have severe consequences like disqualification and astronaut casualties. While simplicity is a design goal, each subsystem must be intricate enough to reliably complete its respective task. Ultimately, the given tasks must be met by optimally utilizing the given resources and time, and exploring different ways to complete each function.

## III. Problem Definition

The problem definition is ultimately defined with respect to the customer's needs. The customers are defined as the judges of the final competition. Ultimately, the customer's wish is for the given machine to score the maximum number of points by performing the final competition tasks. The customer needs were therefore defined in the House of Quality as certain functionalities and attributes of the machine in order to achieve the maximum score.

Figure 1 is a House of Quality for the Mission to Mars final design project. Analyzing the relationship between the demand quality and quality characteristics, it is clear that there are more strong and moderate relationships than there are weak relationships. This demonstrates that the challenge will be to not overstep and attempt to maximize all of the demand qualities. Instead, It will be important to choose certain qualities to focus on in order to prevent complications.

At the top of the house of quality in figure 1 is a correlation matrix for the different quality characteristics. The matrix is dominated by numerous positive correlations, especially in the categories, weight and dimensions. Because of these positive correlations, it will be important to manage dimensions and weight while designing and constructing other specifications such as number of sensors and number of actuators.

Lastly, the bottom section of figure 1 displays the importance value of each quality characteristic along with the target values for specifications. From this figure, the two most important qualities are dimensions and number of subsystems. Both of these qualities are the two most basic and crucial specifications for the device. If the dimensions are even slightly off, the result could be disqualification. Likewise, if there are too many subsystems and over complication, the device may malfunction resulting in disqualification. The single most important challenge during this project will be to stay conscious of the rules and limitations, preventing disqualification.

## IV. Functional Requirements and Constraints

The final design has numerous functional requirements and tasks it must successfully complete, but with limited resources and a large number of constraints. The Function Tree (Figure 9), defines the specific steps that must be satisfied in order to carry out the required functions. On the other hand, the Specification Sheet (Figure 2) specifies the target engineering requirements in order to ensure that each function is properly executed.

The specification sheet in Figure 2 provides specific engineering requirements in order to meet the judges needs. According to Figure 2, the length, width and height of the machine are all required to be an inch below the competition's box dimensions in order to ensure clearance. Additionally, the maximum velocity and acceleration are important, because it is crucial that the machine can move fast enough to grab the astronauts and rovers before competitors, but also slow enough to keep control and avoid crashing or malfunctioning. A maximum velocity of 5 inches per second and a minimum acceleration of 10 inches per second squared ensures both speed and control. Figures 2 also specifies a holding capacity of 10 pounds, even though it needs to hold under a pound. This is more testing the strength of the structure and its ability to hold up in case of a collision. This is in addition to the 50 trial runs test and 3" vertical drop test. Figure 2 also accounts for the allotted energy resources. For example, it lists up to 5 mouse traps with no additional elastic energy. The setup time and task execution time presents challenges, which are specified in Figure 2. Lastly, in order to address safety, there must be insulated wires and no foreign objects sticking out of the machine; therefore, screws must be flush with the surface.

## V. Physical Instantiation of Functions

Reflecting the Function Tree (Figure 9) 's constraints, the morphological chart (Figure 6) displays permutations of possible solutions for the most basic functions listed. It can be seen that the chart concerns itself with three general actions: energy generation, energy transformation, and control. Due to the constraints in energy sources, number of objectives and variety of actions the most difficult of the three categories is energy transformation. With the general objectives of pushing unwanted objects out, gathering desired objects in, detecting acceptable deposit zones and depositing objects into those zones the design has a substantial margin of potential failure. To account for this, the chart can be seen to maintain both simple and broad solutions in order to reduce said complexity. Additional design corrections are expected to be employed in order to ensure the reliable performance from a combination of these solutions.

Integral to the marrying of these sub-systems and control of the overall system will be the use of the MYRIO and signal devices. As a result of the scarcity of switches and sensors, their use will have to be potentially overlapped across sub-systems in order to produce the desired robustness the tasks require.

## VI. Management and Planning Tools

Proper management and planning are crucial to a successful project. Planning tools are a great resource to use in order to ensure a well planned out project that ultimately produces quality products and is executed thoroughly and on time. The planning tools utilized were a Planning Tree Diagram, a Gantt Chart, a Job Responsibilities Matrix and a Specification Matrix.

Figure 6 organizes the project working time via a Gantt chart. This chart breaks down the project into subsystems to be developed over the seven week design period of the project. One of the primary notes of this chart is the recurring evaluation of problem understanding. As the project develops with design options becoming more or less feasible via prototyping and testing, the team should reevaluate their understanding of the problems. Lastly, the team should notice that the workload of the project only intensifies as the weeks progress. It is therefore paramount to make the most of current active weeks by building subsystems that are purposed toward the final build and documenting said development as the project progresses.

The Responsibilities matrix in figure 7 clearly defines an area of focus for each team member and generally defines which tasks will require more attention than other tasks. Based on the figure,  all four team mates will be primarily responsible for brainstorming and concept design phase. Initial design conception is the backbone for the remainder of the project and it is important for every team member to have primary responsibility in this section. After a general design has been decided on, more detailed planning will be committed to sketching, CAD and buying materials. During this process, only one team member will have a primary responsibility on each of the tasks to complete. To execute the plan, construction and labVIEW programing will be needed for multiple subsystems. The subsystems have more primary and secondary responsibility overlapping for team members. This overlap of multiple members being primarily responsible for a subsystem will help ensure that the task is completed and keep members accountable. The tasks with the most members responsible for completing is astronaut rescue and rover collection. These two areas will be the most challenging responsibilities, and will require multiple group meetings throughout the construction phase.

In Figure 8, the planning tool utilized is a prioritization matrix. The matrix was used to prioritize future tasks to be executed for the planning, designing, building and testing processes for the final design project. According to Figure 8, the most important tasks are assembling the machine, practicing competing with the machine, practicing boxing the machine and making machine adjustments. These tasks are more hands on, and involve physically building and testing the machine. While these tasks are the most important, because they involve the actual creation of the final product, the planning steps leading up to this are important as well. In Figure 8, Quality Function Deployment, Product Functions, Specification Development and Conceptual Design are all considered in the design process. The Function Tree was considered to be the most important of these tools, and therefore should be given the highest priority, considering that it will help determine exactly what functions the machine is going to carry out. Ultimately, the prioritization matrix will aid in the decision of time allocation for each step in the design process.

The planning tool shown in Figure 9 is the Function Tree Diagram. The Function Tree help designers divide each task into even smaller and more detailed sub-functions. Though the mechanisms that will be used in the competitions are still not determined, there are some steps that will be involved independent on the type of mechanisms used, like “Trigger Control Signal”, and “Start with Signal”. In the final design, different mechanisms will be chosen for each sub-functions and will be well connected. From this Function Tree Diagram, it can be perceived that as the power sources that can be directly controlled by electric signals (Motors, Solenoids) are limited, some designs that intermediately control energies need to be considered.The connections between signals and these power sources will be carefully designed to achieve the tasks with limited controllers and budget.

## VII. Conclusions

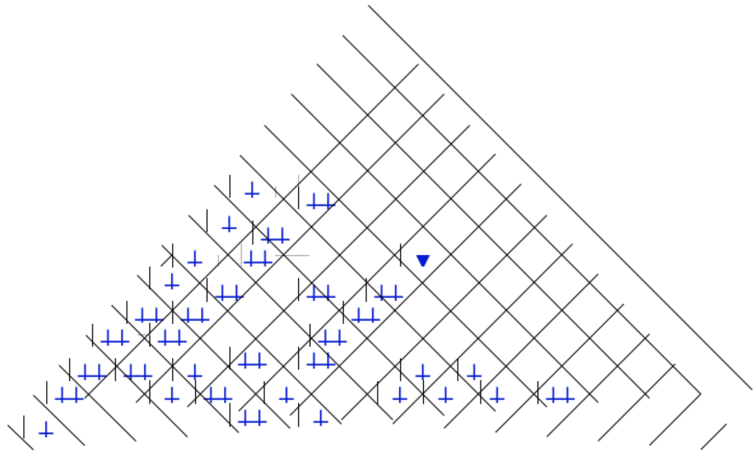
# VIII. Figures and Tables

Title: House of Quality: Mission to Mars Project Planning

Author: Samuel Yatong Audrey George

Date: 2/27/17

Notes: This House of Quality will be used for the project planning report (week 8)



| Row # | Max Relationship Value in Row | Relative Weight | Weight / Importance | Demanded Quality (a.k.a. "Customer Requirements" or "Whats") \ Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") | Weight | Dimensions | Price | Number of Subsystems | Number of Power Source | Range of Extendable Arms | Number of Sensors | Number of Actuators | Area of Protective Barriers | Speed of Operation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Column # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | | | | Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x) | x | ▼ | x | x | ▼ | ▲ | ▼ | ▼ | ▲ | x | | | | | |
| 1 | 9 | 11.3 | 8.0 | Robust | Θ | Θ | O | O | ▲ | | | | O | | | | | | |
| 2 | 9 | 14.1 | 10.0 | Small and Compact | ▲ | Θ | | Θ | Θ | Θ | | O | Θ | | | | | | |
| 3 | 9 | 11.3 | 8.0 | Low Cost | ▲ | | Θ | O | | | ▲ | O | ▲ | | | | | | |
| 4 | 9 | 11.3 | 8.0 | Assembled Quickly | O | Θ | | Θ | ▲ | | O | Θ | | | | | | | |
| 5 | 9 | 14.1 | 10.0 | Operates Autonomously | | | ▲ | | Θ | O | O | Θ | | O | | | | | |
| 6 | 9 | 5.6 | 4.0 | Can Place a Flag | | O | | O | O | Θ | O | O | | ▲ | | | | | |
| 7 | 9 | 5.6 | 4.0 | Land a Space Craft | | O | | O | | | Θ | ▲ | | ▲ | | | | | |
| 8 | 9 | 9.8 | 7.0 | Collect Astronauts and Rovers | | O | | O | | Θ | ▲ | O | | O | | | | | |
| 9 | 3 | 9.8 | 7.0 | Collect Rock Samples | | O | | O | O | O | ▲ | O | ▲ | O | | | | | |
| 10 | 9 | 7.0 | 5.0 | Remove Radioactive Elements | | O | | O | | Θ | | O | Θ | Θ | | | | | |
| | | | | Target or Limit Value | 15-25 lb. | 11x17x23 in. | < 100 $ | 5 | 4 | 12-16 in. | 3 | 4 | 36 - 64 sq. in. | <40 sec.. | | | | | |
| | | | | Difficulty (0=Easy to Accomplish, 10=Extremely Difficult) | 4 | 10 | 6 | 8 | 6 | 9 | 6 | 8 | 5 | 1 | | | | | |
| | | | | Max Relationship Value in Column | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | | | | |
| | | | | Weight / Importance | 161.0 | 443.7 | 149.7 | 409.8 | 322.6 | 400.2 | 174.3 | 407.0 | 244.9 | 175.3 | | | | | |
| | | | | Relative Weight | 5.6 | 15.3 | 5.2 | 14.2 | 11.2 | 13.8 | 6.0 | 14.1 | 8.5 | 6.1 | | | | | |

**Figure 1. House of Quality**

| | | | Issued: February 27, 2017 | |
|---|---|---|---|---|
| | | Specification<br>For: ME 2110 FINAL PROJECT | | |
| Changes | D/W | Requirements | Responsibility | Source |
| | | Machine must carry out each of the tasks required for the final competition, without breaking the given rules. | | |
| | | Geometry: | | |
| | D | Length, 11 in. | Yatong | Instructions [1] |
| | D | Width, 23 in. | Yatong | Instructions [1] |
| | D | Height, 17 in. | Yatong | Instructions [1] |
| | W | Wheel Radius, < 4.5 in. | George | Standard |
| | W | Joint Ranges, 0 - 200 degrees | George | Standard |
| | | Kinematics: | | |
| | D | Max Velocity, 5 in./sec. | Sammy | Standard |
| | D | Max Acceleration, <= 10 in./sec.^2 | Sammy | Standard |
| | | Forces: | | |
| | W | Weight, < 50 lbs | Audrey | Standard |
| | D | Holding Capacity, 10 lbs | Audrey | Standard |
| | D | Pneumatic Tank Air Pressure, < 100 psi | Audrey | Manual [4] |
| | | Materials: | | |
| | D | Stiffness at 15-120 °F, 2.1-10 mpsi | George | YM [5] WS [6] |
| | D | Number of Mousetraps, <= 5 | Design Team | Instructions [1] |
| | D | Number of Pneumatic Tanks, <= 1 | Design Team | Instructions [1] |
| | | Signals: | | |
| | D | Number of False Starts, 0 | Yatong | Instructions [1] |
| | D | Number of External Activation Signals, 1 | Design Team | Instructions [1] |
| | | Energy: | | |
| | D | Elastic Energy Used in Addition to Mouse Traps, 0 J | Sammy | Instructions [1] |
| | D | Max Power Consumption, 18 W | Sammy | [2] |

| | | | | |
|---|---|---|---|---|
| | D | External Kinetic Coefficient of Friction, 0.5-0.8 | Audrey | [3] |
| | | Assembly: | | |
| | D | Set Up Time, < 3.75 min. | George | Instructions [1] |
| | | Quality Control: | | |
| | D | Consistent Operation After 50 Trial Runs, Pass | Design Team | Standard |
| | D | Machine Drop Test, Pass 3" Vertical Drop | Design Team | Standard |
| | | Operation: | | |
| | D | Task Execution Time, < 45 sec. | George | Instructions [1] |
| | | Costs: | | |
| | D | Maximum Materials Budget, $100 | Yatong | Instructions [1] |
| | | Safety: | | |
| | D | Edges, > 90 degrees | Design Team | Standard |
| | D | Percent Screws Flush with Machine Surface, 100% | Design Team | Standard |
| | D | Percent of Insulated Wires, 100% | Sammy | Standard |

**Figure 2. Specification Sheet**

A. Function Tree - 3

B. Morph Chart - 4

C. Planning Tree Diagram - 5

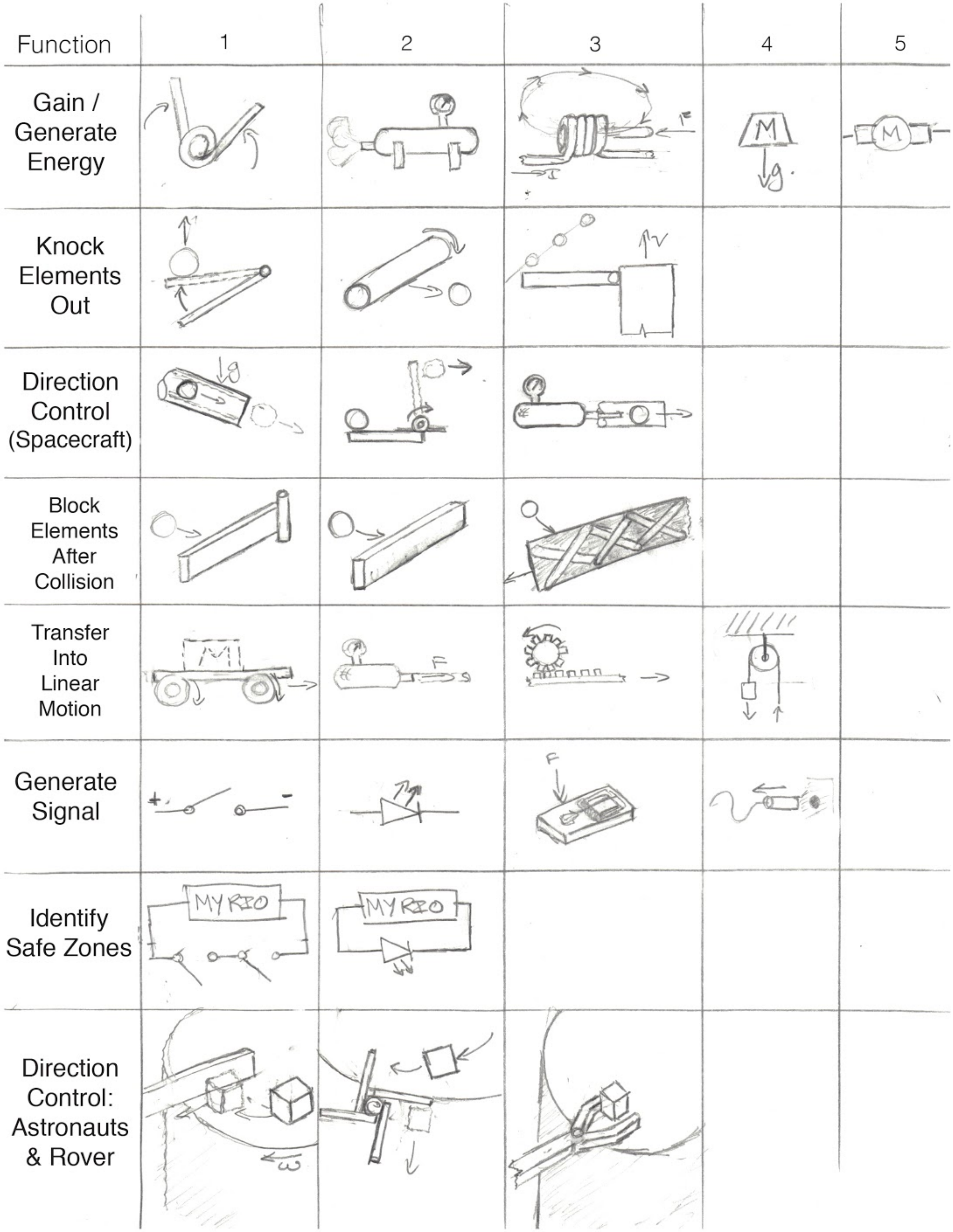



**Figure 3A: Morph Chart**

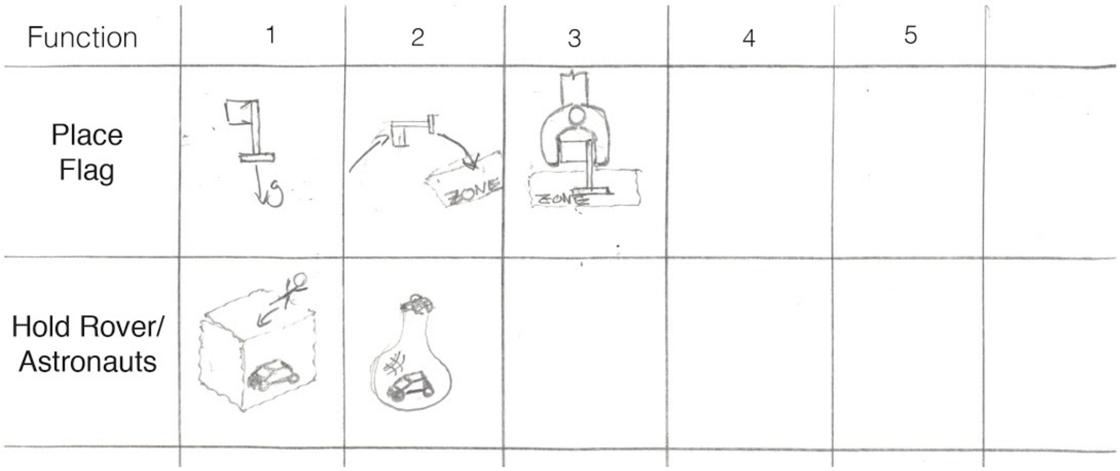



**Figure 3B: Morph Chart Continued**

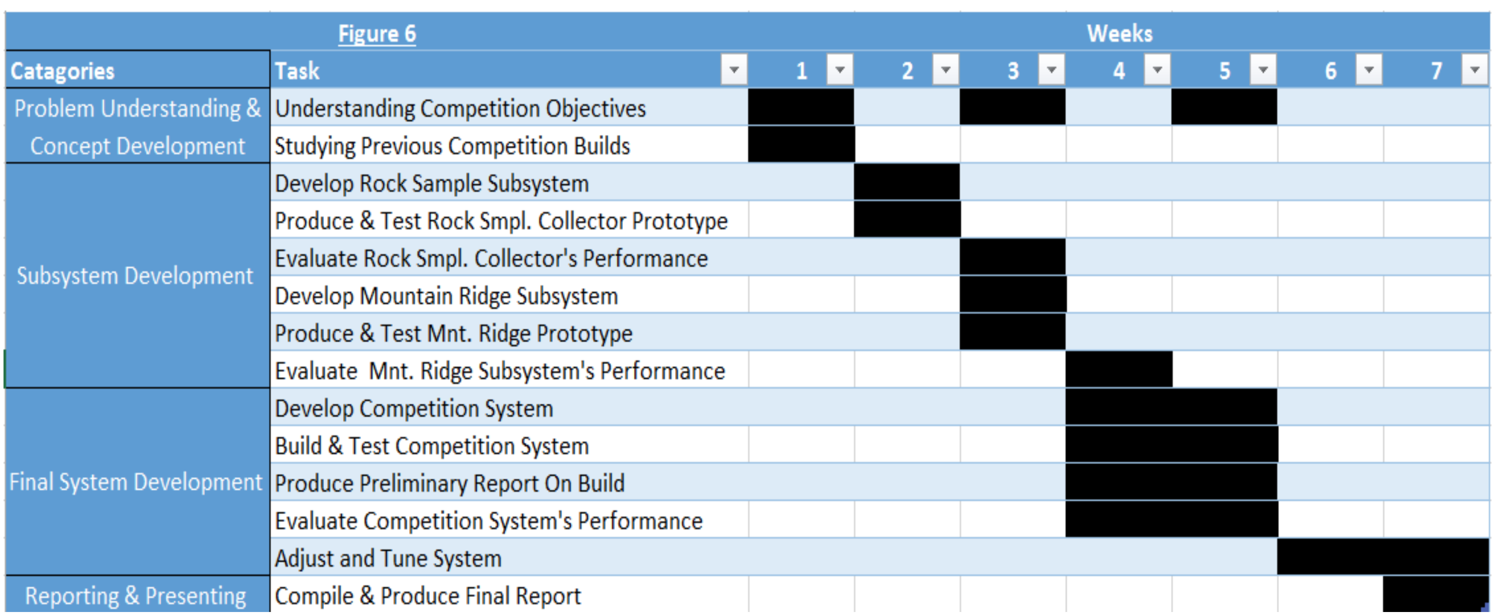



**Figure 6. Gantt Chart**

| | Yatong | George | Samuel | Audrey |
|---|---|---|---|---|
| Concept Design | X | X | X | X |
| Sketching | N | N | X | O |
| CAD | N | X | N | N |
| Order Materials | X | X | N | N |
| LabVIEW Programming | O | X | O | N |
| Mechatronic Design | X | O | O | O |
| Report Writing | O | O | X | X |
| Fabricating | N | X | X | O |
| Plantet Clearing Subsystem | X | N | N | N |
| Rock Collection Subsystem | O | N | N | X |
| Spacecraft Landing Subsystem | X | O | N | X |
| Rover Collection Subsystem | O | X | X | O |
| Astronout Rescue Subsystem | O | X | X | O |
| Flag Plant Subsystem | N | O | O | X |
| | | | | |
| X = PRIMARY RESPONSIBLITY | | | | |
| O = SECONDARY RESPONSIBILITY | | | | |
| N = NEEDS TO KNOW | | | | |

**Figure 7. Job Responsibilities Matrix**

| | | A | B | C | D | E | F | G | H | I | J | K | L | M | N | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brainstorm and Sketch | A | X | - | + | + | - | + | - | + | - | - | - | - | - | - | 19 | 0.038 |
| Research Designs and Materials | B | + | X | + | - | - | + | + | + | - | - | - | - | - | - | 33 | 0.065 |
| Make House of Quality | C | - | - | X | - | - | + | - | - | - | - | - | - | - | - | 17 | 0.034 |
| Make Morphological Chart | D | - | - | + | X | - | - | - | - | - | - | - | - | - | - | 17 | 0.034 |
| Create CAD Drawings | E | - | - | + | + | X | + | + | + | - | - | - | - | - | - | 33 | 0.065 |
| Simulate the CAD on the Track | F | - | - | - | - | - | X | - | - | - | - | - | - | - | - | 13 | 0.026 |
| Prioritize Machine Tasks Using a Function Tree | G | - | - | + | + | - | + | X | + | - | - | - | - | - | - | 29 | 0.058 |
| Make a Specification Sheet | H | - | - | + | + | - | + | - | X | - | - | - | - | - | - | 25 | 0.050 |
| Order Parts and Find Parts | I | + | + | + | + | - | + | - | - | X | - | + | - | - | - | 37 | 0.073 |
| Assemble Machine | J | + | + | + | + | + | + | + | + | + | X | + | + | + | + | 65 | 0.129 |
| Test Each Machine Task; Rate Each Function | K | + | + | + | + | + | + | + | + | - | - | X | - | - | - | 45 | 0.089 |
| Make Machine Adjustments | L | + | + | + | + | + | + | + | + | + | - | + | X | - | - | 53 | 0.105 |
| Practice Boxing Machine | M | + | + | + | + | + | + | + | + | + | - | + | + | X | - | 57 | 0.113 |
| Practice Competing with Machine | N | + | + | + | + | + | + | + | + | + | - | + | + | + | X | 61 | 0.121 |

**Figure 8. Prioritization Matrix**

| | | | |
|---|---|---|---|
| ME 2110-F | | | |
| Yatong Bai, George Garcia, Audley Benson, Samuel Wolfson | | | |
| Function Tree Diagram | | | |
| **Get higher scores than competitors in ME 2110 Big Project: Mission of Mars** | Clear Surface of Radioactive Elements | Knock Elements Out of the Home Zone | Gain / Generate Energy |
| | | | Transmit Energy to Knock Elements Out |
| | | Prevent Elements from Coming Back to the Home Zone | Direction Control |
| | | | Block Elements after Collision |
| | Collect Rock Samples for Study | Reach Out to the Samples | Gain / Generate Energy |
| | | | Transform Energy into Linear Motion |
| | | | Generate Signal for Next Step |
| | | Move Samples Back | Start with Signal |
| | | | Direction Control |
| | | | Gain / Generate Energy |
| | | | Transform Energy into Linear Motion |
| | **Ridge Competition:** Land Spacecraft in Marked Safe Zones | Identify Safe Zones | Identify Safe Zones |
| | | | Trigger Control Signal |
| | | Move Spacecraft to Safe Zones | Hold Spacecraft |
| | | | Gain / Generate Energy |
| | | | Transform Energy into Linear Motion |
| | | | Direction Control |
| | | Drop Spacecraft onto Save Zones | Respond to Control Signal |
| | | | Drop Spacecraft |
| | | Remove Competitors' Spacecrafts from Safe Zones | Start with Signal |
| | | | Remove Competitors' Spacecrafts from Safe Zones |
| | **Ridge Competition:** Retrieve Astronauts | Identify Astronauts | Identify Astronauts |
| | | | Trigger Control Signal |
| | | Reach Out to Astronauts | Gain / Generate Energy |
| | | | Transform Energy into Linear Motion |
| | | | Direction Control |
| | | | Stop with Signal |
| | | Hold Astronauts | Start with Signal |
| | | | Hold Safely when Retrieving |
| | | Retrieve Astronauts | Start with Signal |
| | | | Gain / Generate Energy |
| | | | Direction Control |
| | | | Transform Energy into Linear Motion |
| | | | Stop with Signal |
| | Place National Flag | Reach Out to the Mountain Range | Gain / Generate Energy |
| | | | Start with Signal |
| | | | Direction Control |
| | | | Stop with Signal |
| | | Identify the Mountain Range | Identify the Cavity |
| | | | Trigger Control Signal |
| | | Place the Flag | Start with Signal |
| | | | Place the Flag (Hold or Drop) |

**Figure 9. Function Tree**

## VIII. Sources

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