Studio 3: Final Report

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Executive Summary

The mission to Mars 2110 design competition requires the design and fabrication of a machine to prepare a fictional habitat on a track designed to represent the planet Mars' surface. The machine must complete several mechanical tasks in order to prepare the habitat. It must be able launch spacecraft into designated safe zones, remove boulders from the track, collect supply crates placed on the edge of the track, retrieve objects representing rovers and astronauts, and then egress from the landslide area. The machine will be built from a mechatronics kit and one hundred dollars of materials. Engineering requirements that must be considered include the dimensions of the machine, the horizontal reach of the machine, and the necessary points to win the competition. A successful design must use mechatronics components efficiently for each task and must also fit inside of the required dimensions. The components must operate without interfering with one another, and the machine must be easy to reset after each run. These requirements are the starting point for the planning and design of a well-functioning Mission to Mars machine.

The final design was chosen based on exceeding the scores of other alternatives in reliability, aesthetics, and general overall performance. This design was formulated after the original design was found to have many flaws, namely its repeatability. Qualifying scores were in the negatives, which helped highlight the strengths and weaknesses of the remaining previous design, such as hand fabricated and not laser cut parts and a faulty mountain ridge assembly. The new design features improved mountain ridge and supply crate assemblies complete with laser-cut parts, Delrin motor accessories, and Delrin supply crate arm pivots. The design was aesthetically enhanced with laser cut "Space Jam" themed panels on the sides and back. This lead to a total design review score of 22.3. The team reached the quarterfinals of the competition, winning two of the four matches it competed in and gaining an average score of 102.5 points, with most points coming from supply crates and retrieval of the astronauts and rovers.

This report contains a thorough description of the problem and how the competition was scored, the final design and how it works, and the alternative designs that were also considered. The report also includes the process taken in choosing the final design, and a discussion of the final results of the competition and what did or didn't work when it came down to the final day.

Introduction

Success in the Mission to Mars competition is contingent upon successfully achieving a series of engineering tasks. The competition will take place in the Competition Arena, shown in Figure 1. The machine must be able to retrieve the supply crates on either side of the home zone and clear the boulders from the safe zone area. The machine must also be able to proceed to the cylinder shaped stand in the middle of the track, called the mountain ridge, shown in Figure 2, and recover astronauts and rovers placed on top, shown in Figures 3 and 4. The astronauts and rovers must be collected from the mountain ridge and delivered to the home zone. The machine also must place spacecraft into designated safe zones upon the mountain ridge. Spacecraft launched into non-safe zone will incur a point deduction. Once all these tasks are completed, the machine must exit from the landslide area, at least three inches from the Mountain Ridge.

In order to further organize these tasks to assist in design, the function tree, as shown in Figure 5, was developed. The function tree splits into two branches right after the first item, win design project. This lead to the two separate goals of the project: be aesthetically pleasing to impress the judges, and gain the maximum points possible to win the competition. These were both difficult for different reasons. Impress judges was a difficult task because there is no set standard, different things impress different judges. Therefore, it was difficult to determine what exactly would appeal to all judges. Gaining maximum points was difficult because it requires the machine to complete all tasks, meaning systems must operate efficiently and together. Specific sub functions that were found to be difficult are delivering spacecraft and clearing all the boulders, due to the accuracy each of these functions required.

The House of Quality, shown in Figure 6, highlights some of the most important requirements. Among them, the machine must be able to fit in the starting box, with outside dimensions of 1ft by 2ft by 1.5 ft. If this is not accomplished the machine will be disqualified, getting the least possible amount of points. The inner dimensions of the box have an estimated tolerance of +/- 0.5 inches. The machine also must have materials costing under $100, and be able to gain a certain amount of points each run.

The House of Quality also assigns weights to each task based on their importance. The tasks completed on the mountain ridge, along with the egress to safety, have the highest importance, followed by supply crates and boulders. These weights are assigned based on the point values for each task, and if the task is challenged by other teams or not. Spacecraft are high importance because there is no competition with other machines to complete this task, whereas supply crates and astronauts and rovers are challenged by other teams. This means there is no guarantee that these points can be won. The House of Quality also shows other key customer needs of the machine such as its repeatability, accuracy, and safety of the track. These tasks were each ranked of high importance because the machine must be able to perform multiple runs in the competition, be accurate in each run so as to provide consistent results, and be safe to those around it to prevent injury or disqualification. The engineering requirements in the House of Quality show that the machine has a maximum starting size, but also must have a minimum reach in both the horizontal and vertical directions in order to reach supply crates, rovers, and astronauts. The low budget of the engineering material places serious constraints on designs and will require creative solutions to complete all of the tasks in the assigned manner. The machine must be able to repeat its run, as multiple runs are performed in the competition.

Two air cylinders, two DC motors, two solenoids, and five mousetraps are the only sources of power that can be used. The strength and power of these sources are shown in the specification sheet, figures 7A and 7B. Other key specifications shown in the specification sheet are the machines starting length width and height, as if the machine is too large it will disqualify. Also key is the machines set up and run time, as these could also cause disqualification if not correct.

The first objective of the design is to progress to the mountain ridge as quickly as possible in order to collect astronauts and rovers before other teams. Realistically, one rover and one astronaut will be collected for 28 points each, so it is important to consider that points from all four may not be possible. The spacecraft will all be deposited into greenlit safe zones for 15 points each. The following egress to safety doubles astronaut and rover points. The objective of supply crate arms is to collect all eight supply crates for 80 points, and clear the two outmost boulders. The center boulder is left, due to the complexity of an extra system to gain just six points. The total objective is to score 150 points in this manner, with around 150 points expected to win most rounds.

System Description

The final Space Jam design, His Airness, has boxed dimensions of 11 in. wide, 23 in. long, and 16 in. tall, as shown in Figure 8. When deployed, His Airness appears as in Figure 9. His Airness is composed of two subsystems: the mountain ridge assembly and the pivot arm assembly. The machine is expected to reliably score 150 points per round: four supply crates, 4 successful spacecraft landings, 1 astronaut/rover (x2 egress), and 2 boulders removed as shown in Table 2. The bill of materials, shown in Figure 10, breaks down the cost of the machine. The total cost is $94.96, due mostly to the cost of the drawer slides and Delrin. The main cost-related challenge was deciding which components would be made of better materials.

The machine operates with two main subassemblies. The mountain ridge assembly, shown in Figure 11, collects astronauts and rovers, delivers spacecraft, and egresses. The pivot arm subsystem, shown in Figure 12, collects supply crates and clears the two outermost boulders. The Pivot arm subsystem relies on the Mountain Ridge assembly to activate: the arms are deployed by the movement of the Mountain ridge assembly, meaning the systems work together.

Operation begins once the track is started. A pneumatic cylinder activates and hits the starting block, shown in the mountain ridge subsystem in Figure 11. This extends the drawer slides to their full length, deploying the scythe arms and moving the mountain ridge assembly into position. The mountain ridge assembly consists of a spacecraft container, a solenoid to release the spacecraft, a mousetrap deployed ridge arm, and a long arm switch to detect safe zones. If the switch is triggered twice in one second, the solenoid releases the spacecraft. After 30 seconds, the large motor begins pulling the assembly out of the landslide zone.

The Pivot Arms Subsystem achieves two objectives: retrieving the supply crates and clearing the two outer boulders from the habitat area. Once deployed by the drawer slides, the scythe arms are pulled back by a dropping weight initiated by pneumatic cylinder, as shown in Figure 12. The arms, connected to pivots made of Delrin and shoulder screws, move with little friction to collect the crates. Furthermore, the upper portion of the arms also clears the outermost boulders from the habitat zone in its motion. This combining of tasks allows for less components in the overall design.

Concept Alternatives

Three alternative concepts were developed to possibly achieve the task: The Barkley, the Bird, and the Magic Johnson. The Morph Chart, shown in Figure 13, contains the different ideas for each task which were applied across the different potential designs. Boulder clearing was found to be a more difficult task, as any system must have such a wide reach yet also coexist with the other, higher importance systems. Mountain ridge tasks were found to be the easier to design, although many ideas were similar.

The Barkley, shown in Figures 14 and 15, also uses drawer slides, however its mountain ridge assembly flips up and out on mousetraps to achieve the proper distance. This was originally chosen to be the final design before qualifying. However, due to the unreliability of the mouse traps, which continued to break every few runs, we had to seek alternatives in order to reach the mountain ridge consistently. This mountain ridge assembly, as shown in Figure 16, consists of the spacecraft container with a solenoid used to release the spacecraft once the long arm switch is triggered twice. The supply crate assembly, shown in Figure 17, consists of two arms on hinges, deployed by the drawer slides hitting them. They are then pulled back by a dropping weight, spinning the arms to the edges of the home zone by rotating pivots. Finally, the boulder clearing assembly as shown in Figure 18 consists of a folded arm contained under the mountain ridge assembly. When the mountain ridge assembly is fully extended, the small motor pulls the boulder arm off of the ledge, where mousetraps extend the boulder arm to full length. It is then pulled back, with the boulders, to the machine.

The Bird, shown in its starting position in Figure 19, was designed with accuracy, speed, and repeatability in mind. The machine uses the same arms that retrieve the supply crates to clear the boulders from the habitat area, shown in the deployed view in Figure 20. These arms are rotated by a string tied around their circular bases and connected to a motor, causing the boulders to be cleared from the habitat zone, and the supply crates to be collected into the home zone.

In order to put the mountain ridge within reach, there is a rack and pinion system mounted onto steel drawer slides that will extend into the habitat zone, as shown in Figure 20. When triggered, the extendable arm with the basket, shown in the deployed view, will be pushed out by the pneumatic cylinder. When the drawer slides are fully extended, the rack and pinion system, shown in Figure 21, will extend the basket assembly to the mountain ridge. At the mountain ridge, the solenoid holding the spacecraft in the spacecraft tube will retract, releasing the spacecraft after a long arm switch detects the safe zone. The angled wedge will knock the rovers and astronauts into the basket, although there are concerns the basket may not be large enough.

The Magic Johnson, shown deployed in Figure 22, was designed to maximize time efficiency, and precision. The machine is split into three primary subsystems. The Boulder Clearing Subsystem is initiated when the Pneumatic Cylinder fires and contacts the Boulder Extension Block as shown in Figure 23. This force causes the rest of the subassembly to travel into the habitat zone via an 18 inch Drawer Slide. A pin is pulled out causing the mouse traps to extend the collection walls. The small motor activates and pulls in the boulders with the collection walls into the starting zone. The supply crate Subsystem, shown in Figure 24, begins when the force of the mountain ridge subsystem pushes the collection arms forward into the home zone. The large solenoid fires causing the weight to drop. The weight pulls a string, through a system of pulleys, that rotates the Pivots on which the arms are attached. This brings the collection arms back into the wider area of the habitat zone, along with the supply crates. The Mountain Ridge Subsystem is shown in Figure 25. The pneumatic cylinder fires and contacts the Mountain Ridge Extension Block, forcing the assembly down the 22 inch drawer slides. A pin is pulled out causing the Mouse Traps to extend the Spacecraft Container, Basket, and Ridge Collection Arm. The small solenoid fires releasing the spacecraft into the safe zone once the long arm switch is triggered twice. The large motor pulls back the Mountain Ridge Subsystem away from the landslide zone once tasks are completed.

Concept Evaluation

The Pugh Chart, shown in Figure 26, was the beginning of the evaluation of each concept. Using the Bird Design as the Datum, the Magic Johnson design was evaluated as being less effective than the Datum. The Barkley and His Airness Designs both performed higher due to their ability to retrieve supply crates, remove boulders, and their overall maneuverability.

With this knowledge in mind the third degree evaluation matrix shown in Figure 27 was developed. Evaluating the customer needs from the House of Quality with weights assigned, His Airness had the highest fractional score. His Airness exceeded the others on the highly weighted tasks of Speed of Operations and Accuracy in completing Tasks. Speed of Operations is crucial because for the astronauts, rovers, and the supply crates the machine must beat its competitors in collecting these. Accuracy in completing tasks is crucial as the machine must perform as consistently as possible to garner respectable scores throughout the competition. His Airness also scored highly in the Mountain ridge tasks, which have the most points. For these reasons it was selected as the final design.

Discussion

Three smaller competitions involving the teams and machines were held leading up to the final competition. The results from each of these competitions, as well as those of the final competition, are shown in Table 3. The first competition tested the machines ability to retrieve supply crates. While the machine gathered close to half the supply crates on average, around it was determined that the small DC motor was not providing the desired speed to pull the arms back along a pivot point around a screw. Instead, a weight and pulley system was to be used. This also led to the decision to use Delrin bases on shoulder screws to allow for less friction in the rotation, and re-design the arms to have a more appealing shape: both to impress judges and to allow the crates to better collect within the habitat zone.

The next competition tested the machine's ability to complete the Mountain Ridge tasks. It was expected that the machine would be able to deliver spacecraft and collect at least partial credit for rovers on this task. The machine did not perform well for this task, however, as the drawer sliders were found to be easily triggered resulting in one disqualification, and the negligence of a team member resulting in another. The mountain ridge competition did begin to expose some of the downfalls to the mousetrap extended assembly, such as its tendency to fail after a certain amount of tests and its lack of precise positioning. This led to using the double drawer slider system before qualifying.

The machines performance for qualifying was better than that in the mountain ridge competition, however still left much to be desired. It was not expected to be very successful, as many systems were still being redesigned from the previous mountain ridge competition. With only the mountain ridge assembly in operation, the machine showed progress in its ability to both advance to the mountain ridge and make the egress required.

Several design changes were made after qualifying. The majority of the mountain ridge assembly and supply crate arms were laser cut to provide exact dimensions as well as to be more aesthetically pleasing. These new parts, once assembled, proved to be much more reliable as they were the exact dimensions the design called for. The supply crate arms were laser cut and attached to the Delrin mounts and the weight, put in motion by an air cylinder. The supply crate arms were also adjusted to clear the two outermost boulders, allowing the boulder clearing assembly to focus on a single boulder. The most importance was placed on the mountain ridge, as it was seen as an area where the machine could not be affected by other machines but also score high amounts of points. Lesser importance was placed on the collection of supply crates for two reasons; the first reason was that the machines system appeared slower than other machines and the second was that other machines seemed to routinely push supply crates into neighboring areas, so it was believed points from supply crates would be aided by other machines. Clearing boulders was giving importance, however the middle boulder was left as a last minute project due to its low point value. This leads to the machine being very strong in the mountain ridge assembly: specifically consistent delivery of the spacecraft to the safe zones and consistent completion of the egress. The main weakness of the design appears to be its supply crate collection device; although it is still a much improved assembly from its first testing in the supply crate competition.

Final competition results were positive, however some design flaws made themselves present. The machine advanced to the quarterfinals, winning two of its four matches with scores of 130 both times. The spacecraft delivery system developed issues not seen previously, not releasing spacecraft at the proper time and sometimes not at all. These issues were previously unseen, and prohibited the machine from performing at its full potential.

Conclusion

This report has highlighted the process of the design of the final His Airness machine, from the problem to how the team decided upon the His Airness design. An analysis of design alternatives considered, complete with a rationale for why the final design was decided upon is also included. A discussion of the machine and its previous performance, as well as how the machines performance improved with each change in idea is also included. A rendering of the final machine developed is shown in Figure 28.

The team learned the efficiency of laser cutting parts where precision is needed, and doing this sooner in the design process would have yielded better results in earlier competitions. More importantly, R & D skills were acquired throughout the competition. When ideas failed the team learned to realize what could be adjusted to work, or when a component might need to be completely redesigned in order to adequately complete its desired task. Finally, the idea that sacrifices must be made in any design process was a big learning step. To work multiple tasks, there would have to be tradeoffs: for example, using the air valves to deploy the drawer sliders and weight meant they could not be used for a quicker supply crate retrieval.

Space Jam placed ninth in the final competition after being ranked twenty-second in qualifying. The supply crate and boulder clearing subassembly performed as expected, collecting three supply crates and clearing two boulders each run on average. The solenoid failed to allow the spacecraft to pass on to the safe zone during three of four runs. The problem was that the spacecraft container was too narrow to allow the spacecraft to move through when the solenoid fired. More testing could have revealed this flaw. The arm for collecting the astronauts and rovers was not always accurate, occasionally displacing items to the wrong area. Space Jam placed modestly in the final design review, scoring a 7.3 in presentation, an 8.0 in aesthetics, and a 7.0 in ingenuity.

Space Jam could have improved final competition results in many ways. An adjustment to the shape of the supply crate arms could have been made to collect more supply crates, and the final design could have accounted for the center boulder. On the mountain ridge subsystem, the spacecraft container should have been marginally wider in order to ensure release of the spacecraft. The presentation at design review could have used more practice. The aesthetic appeal of the machine was hindered by the lack of color, although the laser cut parts provided a clean-cut look. If able to make further changes to the design, the team would fix the spacecraft deployment system as previously mentioned and improved the supply crate collection.

Appendix

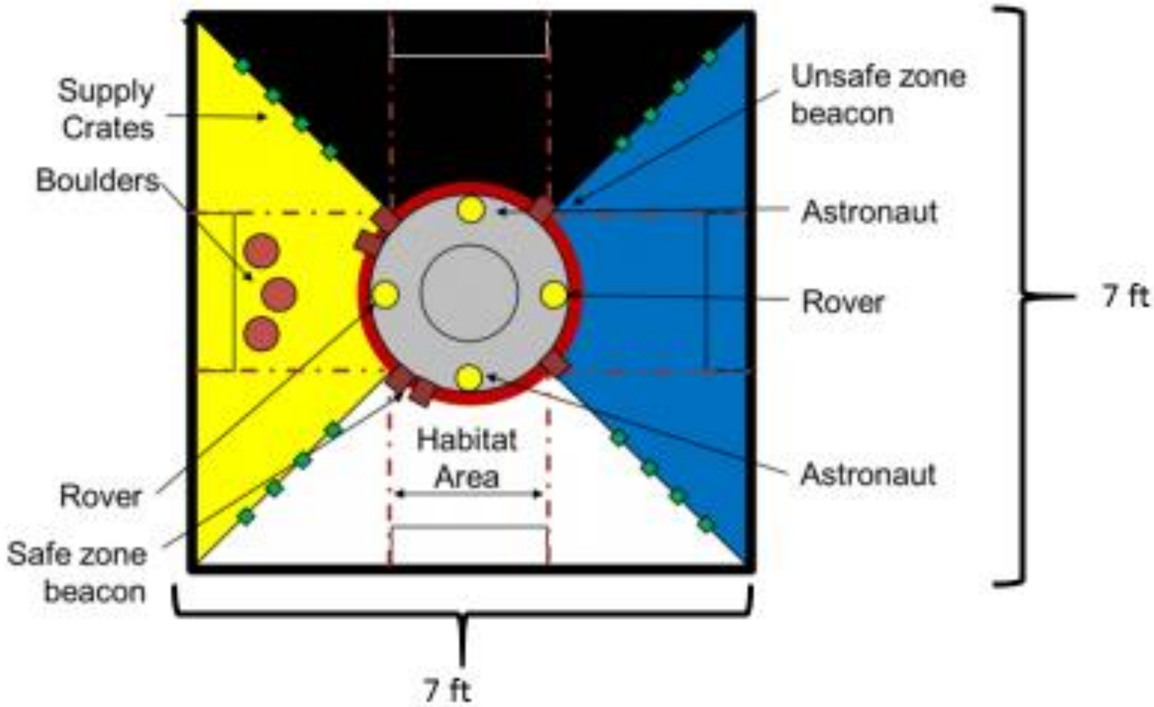


Figure 1: The Competition Arena Top View

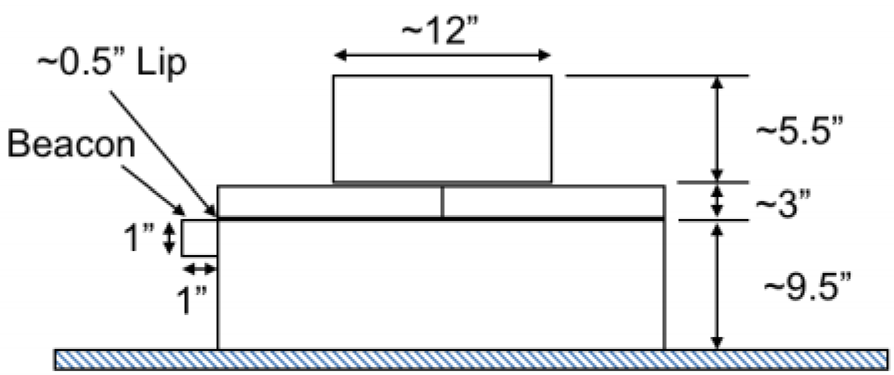


Figure 2: Mountain Ridge Side View

Figure 3: Rover (3D printed object) approximately 1.5 to 2.5 inches in height

Figure 4: Astronaut (3D printed object) approximately 4.5 inches in height

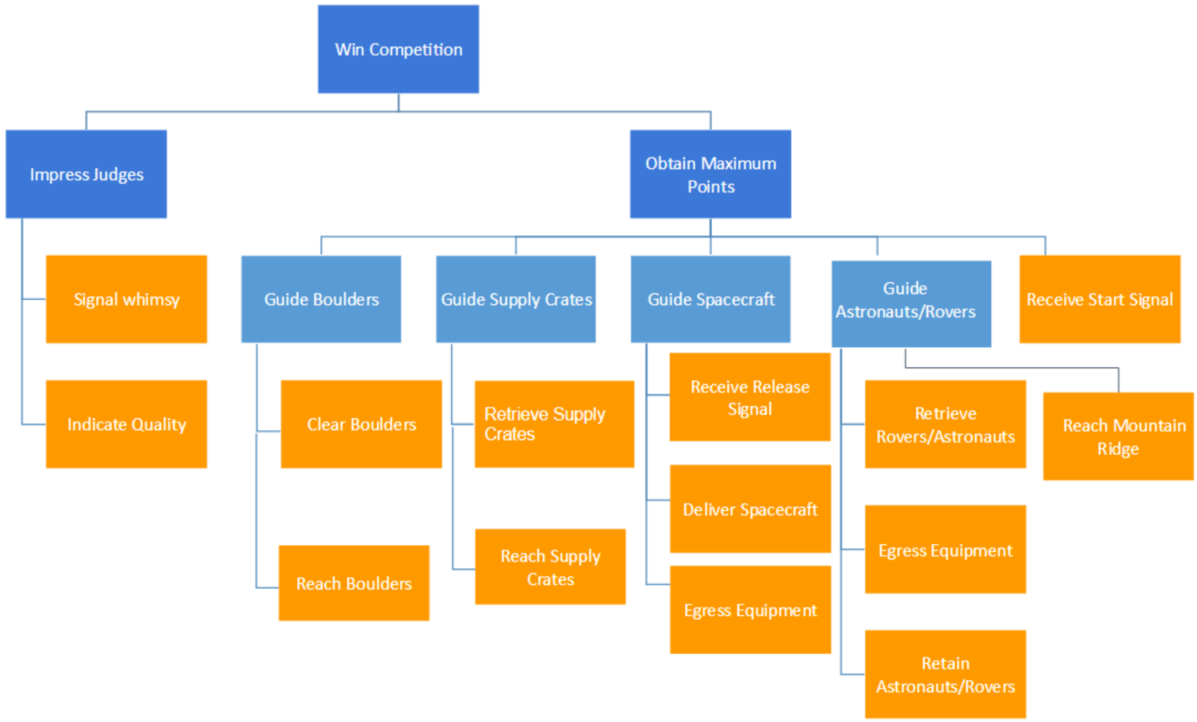
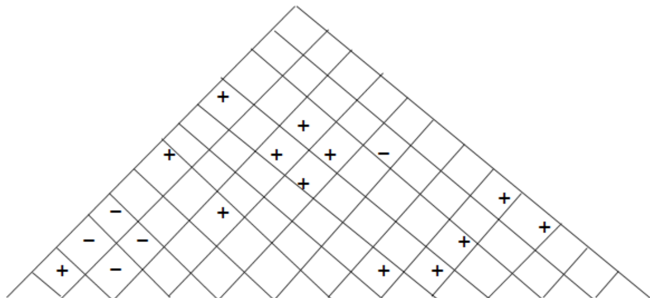


Figure 5: Function Tree

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



		Column #	1	2	3	4	5	6	7	8	9	10	11	12
		Direction of Improvement	▼	▼	◇	◇	▼	▼	▼	▲	▲	▲	▲	▼
Category	Weight (1-7)	Engineering Requirements / Customer Requirements (Explicit and Implicit)	Start Size	Weight	Horizontal Reach	Vertical Reach	Material Cost	Preparation Time	Run Time	Points to win	Points from ridge	Points from habitat floor	Lifetime Runs	Time to reach mountain ridge
Competition Requirements	3	Remove Boulders	●	○	●		○	●	●			●		
	4	Retrieve Supply Crates	●	○	●		○		●	●		●		
	5	Deliver Spacecraft	●	●	●	●	○	●	●	●	●			○
	6	Retrieve Rovers and Astronauts	●	●	●	●	○	●	●	●	●			●
	5	Egress Rescue System	●	●			○		●	●	●			
Good Machine Qualities	5	Easily Manueverable	●	●				○	▽	○	○	○		○
	3	Low Cost					●			▽			▽	
	7	Operates under time constraints		▽				●	●					
	5	Easily reset							●	○	○	○	▽	
	3	Safety of track		●			▽							
	7	Accuracy in completing tasks							●	●	●	●		●
		Target	<11" x 23" x 17"	<20 lbs	~24"	~15"	<$100	3 minutes	45 seconds	>100 points	>60 points	>40 points	50< runs	<3 seconds
		Technical Importance Rating												

Figure 6: House of Quality

D/W	Requirement	Target Value	Responsibility	Source
	Boulder in Zone	-6 points	All	ME 2110 Studio 3 [6]
	Successful Spacecraft Deposit	15 points	All	ME 2110 Studio 3 [6]
	Astronaut in Home Zone	28 points	All	ME 2110 Studio 3 [6]
	Supply Crate in Home Zone	10 points	All	ME 2110 Studio 3 [6]
	Geometry			
D	Maximum Initial Machine Width	11 +/-0.5 in	All	ME 2110 Studio 3 [6]
D	Maximum Initial Machine Length	23 +/-.5 in	All	ME 2110 Studio 3 [6]
D	Maximum Initial Machine Height	17 +/-.5 in	All	ME 2110 Studio 3 [6]
W	Forward Displacement	54 in	Luke	Approx. Length to get to Mountain Ridge
W	Height to Release Spacecraft	9.5 to 12.5 in	Chance	ME 2110 Studio 3 [6]
W	Minimum Distance from Ridge at End Time	3 in	Luke	ME 2110 Studio 3 [6]
D	Supply Crate Side Lengths	2 in	All	ME 2110 Studio 3 [6]
D	Space Craft Diameter	40 mm	All	ME 2110 Studio 3 [6]
D	Boulder Width	3 in	All	ME 2110 Studio 3 [6]
D	Boulder Length	4 in	All	ME 2110 Studio 3 [6]
D	Habitat Area Width to Clear	30 in	Chance	ME 2110 Studio 3 [6]
D	Track Width	7 ft	All	ME 2110 Studio 3 [6]
	Energy			
D	Air Reservoir Operating Pressure	25-100 psi	All	Mechatronics and Pnematics kit Manual [7]
D	Pnematic Actuator Working Pressure	1.2 to 10 bar	All	ESNU-20-50-P-A Spec Sheet [5]
D	Gravity	9.83 m/s2	All	993-1033-ND Spec Sheet [2]
	Safety			
D	Percent of Parts that are Secured	100%	Luke	Inhibit Potential Projectiles
W	Number of pieces of splintering wood	0	Chance	Desired Surface Finish
	Quality Control			
W	Minimum Amount of Runs Durable For	100	Chance and Luke	Desired Maintenance of Structure
	Operation			
D	Maximum Time To Set Up	3:45 min	All	ME 2110 Studio 3 [6]
D	Maximum Runtime	45 sec	Clay	ME 2110 Studio 3 [6]
W	Maximum Runtime post Retraction	40 sec	Clay	ME 2110 Studio 3 [6]
D	Maximum Time including Clean Up	8 min	All	ME 2110 Studio 3 [6]
W	Boulders Moved from habbitat zone	# 3	All	Desired Points, ME 2110 Studio 3 [6]
W	Min Astronaut/Rover to Collect	# 1	All	Desired Points, ME 2110 Studio 3 [6]
W	Number of Space Craft to Land Safely	# 4	All	Desired Points, ME 2110 Studio 3 [6]
W	Number of Suppy Crates to Collect	# 8	All	Desired Points, ME 2110 Studio 3 [6]
	Cost			
D	Total Cost (Excluding given supplies)	$100	All	ME 2110 Studio 3 [6]
	Kinematics			
D	Mouse Trap Angular Displacement	180 Degrees	All	Estimated on Visual Analysis
D	Small Solenoid Stroke Length	1/2"	All	69905K4 Spec Sheet [4]
D	Large Solenoid Stroke Length	1"	All	69905K6 Spec Sheet [4]
D	Pnematic Cylinder Stroke Length	50 mm	All	ESNU-20-50-P-A Spec Sheet [5]
D	Permanent Magnet (PM) DC Motors with Spur Gearboxes - Large	57 RPM	All	BDSG-37-40-12V-5000-R75 Spec [3]
D	Permanent Magnet (PM) DC Motors with Spur Gearboxes - Small	43 RPM	All	BDSG-37-30-12V-5000-R100 Spec [3]
D	Mountain Ridge Angular Velocity	5-7 RPM	All	ME 2110 Studio 3 [6]
D	max Working Force 6mm Tubing	240 psi	All	9355T2 Spec Sheet [3]
	Materials			
D	Number of Adhesive/Velcro Material Interaction with Track	0	Luke	ME 2110 Studio 3 [6]

Figure 7A: Specifications Sheet

	Ergonomics			
W	Easy to Grip	TRUE	Chance	Desired for Transport
	Assembly			
D	Potentiometer	# 1	All	Mechatronics Kit Components
D	PushButton Switch	#1	All	Mechatronics Kit Components
D	Long-Arm Switch	#2	All	Mechatronics Kit Components
D	Roller Switch	# 1	All	Mechatronics Kit Components
D	IR Sensor	#1	All	Mechatronics Kit Components
D	Small DC Motor	#1	All	Mechatronics Kit Components
D	Large DC Motor	#1	All	Mechatronics Kit Components
D	Pnematic Actuators	#2	All	Mechatronics Kit Components
D	Small Solenoid	#1	All	Mechatronics Kit Components
D	Large Solenoid	#1	All	Mechatronics Kit Components
D	Mouse Traps	#5	All	Mechatronics Kit Components
D	Encoder	#1	All	Mechatronics Kit Components
D	Pnematic Valve	#2	All	Mechatronics Kit Components
D	Needle Valve	#1	All	Mechatronics Kit Components
	Signals			
D	Number of Start Signals	#1	Clay	ME 2110 Studio 3 [6]
D	Start Signal Type	Closed Loop	Clay	ME 2110 Studio 3 [6]
	Schedule			
D	Boulder Clearing Subsystem	14 June	All	ME 2110 Studio 3 [6]
D	Supply Crates Collection Subsystem	21 June	All	ME 2110 Studio 3 [6]
D	Mountain Ridge Subsystem	28 June	All	ME 2110 Studio 3 [6]
D	Qualifying System	10 July	All	ME 2110 Studio 3 [6]
D	Finalized System	14 July	All	ME 2110 Studio 3 [6]
	Forces			
D	Small Solenoid Pull (Continuous)	4 oz	All	69905K4 Spec Sheet [4]
D	Large Solenoid Pull (Continuous)	5 oz	All	69905K6 Spec Sheet [4]
D	Pnematic Actuator Force (at 6 bar)	169 N	All	ESNU-20-50-P-A Spec Sheet [5]
D	Large DC MOTOR Torque	54 oz-in	All	BDSG-37-40-12V-5000-R75 [3]
D	Small DC MOTOR Torque	36.11 oz-in	All	BDSG-37-30-12V-5000-R100 [3]
	Maintenance			
W	Amount of Runs Repeatable Before Maintenance	20	All	Amount of Times Device will Run in Competion + Margin
	Production			
D	Componenets Producible with Open Lab/Invention Studio Resources	TRUE	All	Desired Production Method
	Transport			
W	Maximum Machine Weight	50 lbs	Luke	OSHA [1]
W	Maximum Number Of People Required to Move	# 2	Chance	Desired Method of Transport
	Recycling			
D	% of Retrievable Mechatronics Components	100%	Chance	Required To Return Mechatronics Components

Figure 7B: Specifications Sheet

Table 1: Point Values

Task	Competition Point Value
Boulders	-6 per boulder (full or partial)
Supply Crates	10 per crate (full)
Spacecraft	15 per safe landing -20 per unsafe landing
Rover	28 per rover (full) 14 per rover (partial)
Astronaut	28 per astronaut (full) 14 per astronaut (partial)
Egress	Doubles astronaut and rover scores

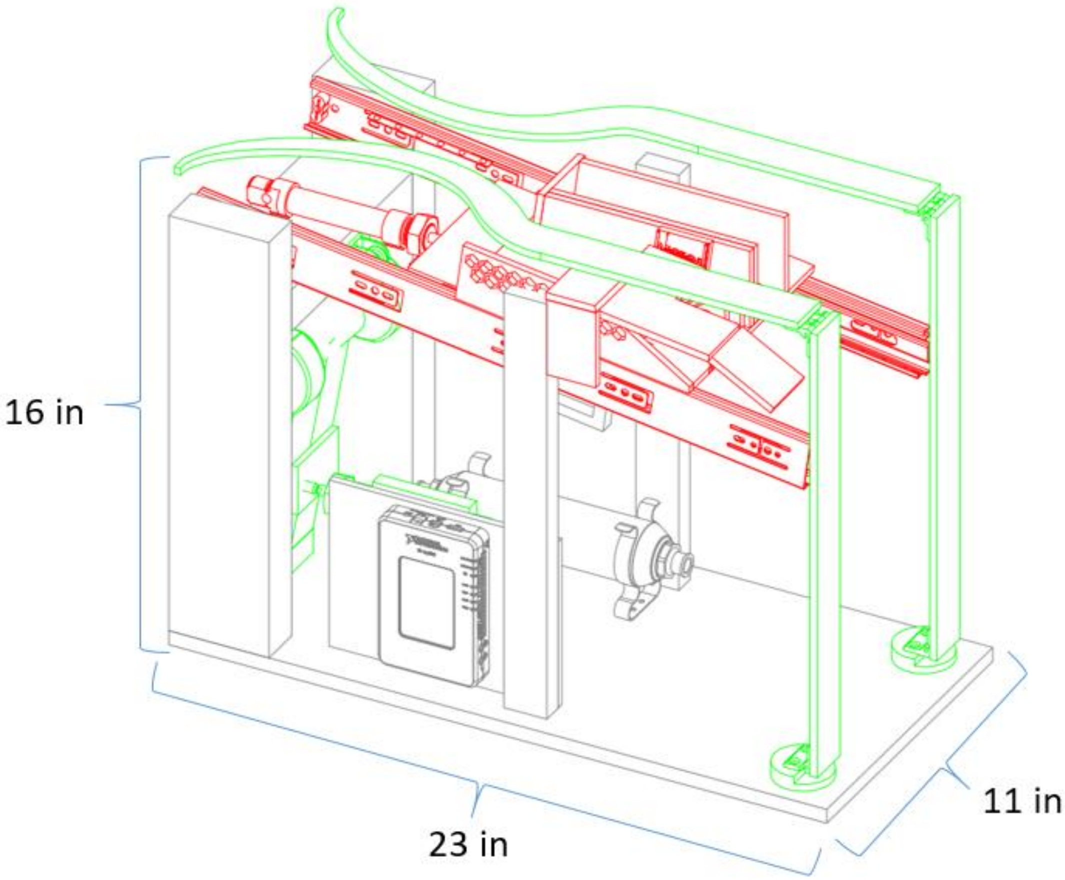


Figure 8: His Airness Boxed View

Additional CAD model sources: 22” Drawer Slides [8], Large Motor [9], Pneumatic Cylinder [10], Air Reservoir [11], MyRio [12], Mouse Trap [13]

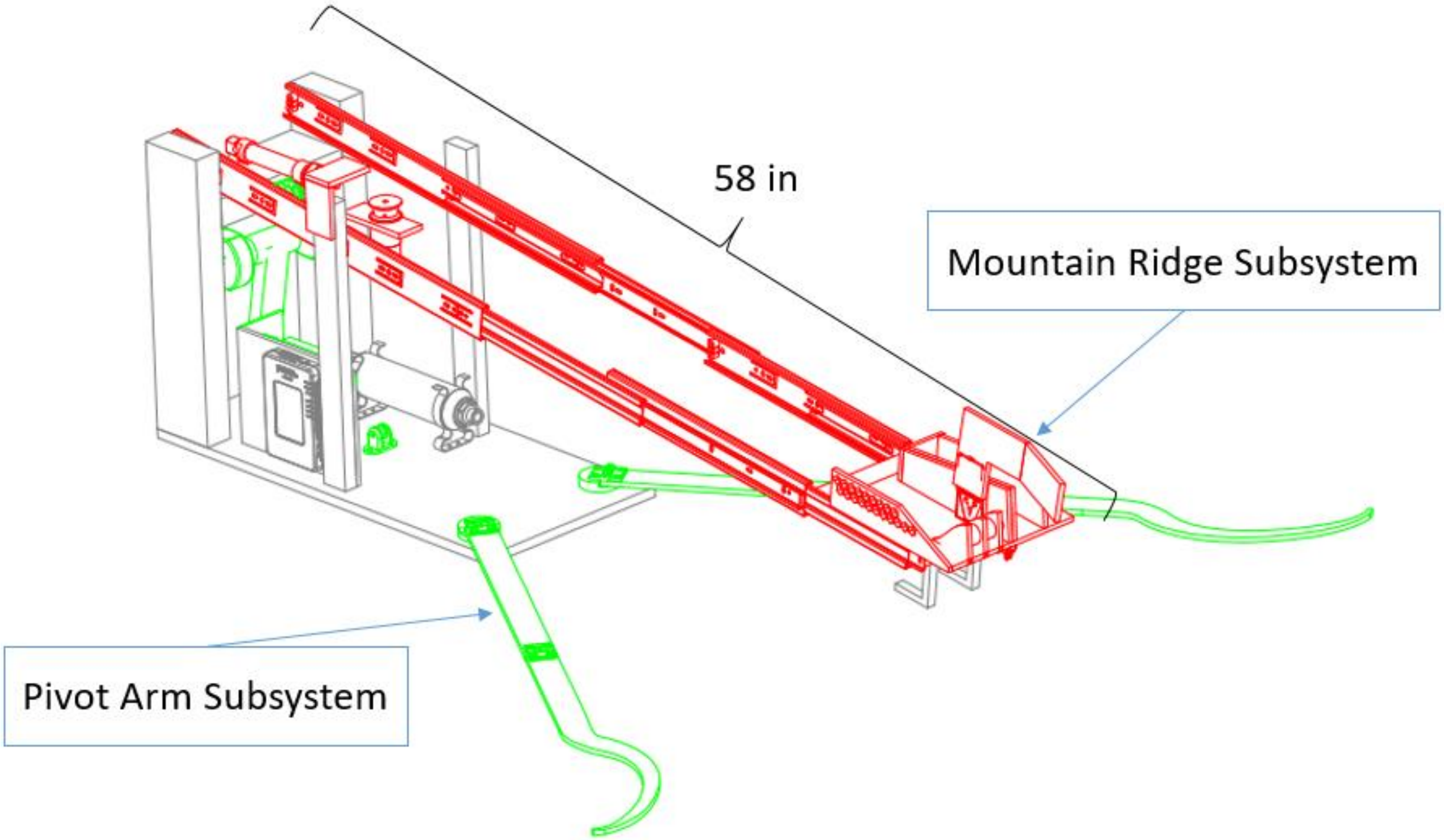


Figure 9: His Airness Deployed View

Red components correspond to Mountain Ridge Subsystem. Green components correspond to Pivot Arm Subsystem

Table 2. Estimated Points per Round Calculation

Item	Estimated Amount	Points
Supply Crates	**4**	**40**
Spacecraft Landing	**4**	**60**
Astronaut/Rover	**1 (x2 for Egress)**	**56**
Boulders Removed	**2**	**-6**

	Total	150

Part Name/Description	Part Number	Manufacturer	Quantity	Unit Cost	Total Cost	Source
22 inch Drawer Slides Pair	Model # D80622C-ZP-W	Liberty	1	15.48	15.48	1
14 in Drawer Slides Pair	Model # D80614C-ZP-W	Liberty	1	11.48	11.48	2
Pulley	3071T7	McMaster-Carr	2	8.22	16.44	3
2" Delrin Rod	8572K29	McMaster-Carr	6 in	18.04 per ft	9.02	4
1/4" Plywood	Model # 448887	Tri-Ply	1 Sheets	9.49	9.49	5
1 x 2 Scrap	Model # 315412	WeatherShield	30"	1.87 per 8ft	0.59	6
2x4 Scrap	Model # 161640	Home Depot	30"	3.29 per 96 in	1.03	7
2x6 Scrap	Model # 161713	Home Depot	10"	5.60 per 8ft	0.59	8
23/32" plywood Scrap	Model # 1502014	Home Depot	11"x 23"	7.48 per 24" x 24"	3.74	9
Paracord	Model # 12715	Everbilt	1	2.97	2.97	10
Spring	Model # 13554	Everbilt	1	4.37 per 84	0.06	11
3/4 in. Zinc Plated Corner Braces	Model # 13542	Everbilt	8	1.97 per 4	3.94	12
18-Gauge Galvanized Steel Angle	Model # A21	Simpson Strong-Tie	1	0.67	0.67	13
1-1/2 in. Zinc-Plated Narrow Utility Hinge	Model # 15396	Everbilt	5	2.27 per 2	5.67	14
1/2 in. x 6 in. Heavy Duty Beige Felt Strips	Model # 49954	Everbilt	1 box	3.48 per box	3.48	15
5lb Weight	Model # 551486379	CAP Barbell	1	4.87	4.87	16
3lb Weight	Model # 551486380	CAP Barbell	1	2.96	2.96	17
2 in. Zinc-Plated Mending	Model # 15299	Everbilt	4	2.48 per 4	2.48	18
				Total	94.96	

Raw Material Estimates	
2x4	(30/96) *3.29 = 1.028125
2x6	(10/96)*5.6 =0.59
23/32" plywood	7.48/2 = 3.74
1 x 2	(30/96)*1.87 = .59

Sources

1	http://www.homedepot.com/p/Liberty-22-in-Full-Extension-Ball-Bearing-Side-Mount-Drawer-Slide-1-Pair-D80622C-ZP-W/202200646
2	http://www.homedepot.com/p/Liberty-14-in-Full-Extension-Ball-Bearing-Side-Mount-Drawer-Slide-1-Pair-D80614C-ZP-W/202200642
3	https://www.mcmaster.com/#3071t7/=18gcruk
4	https://www.mcmaster.com/#8572k29/=18h365q
5	http://www.homedepot.com/p/Sande-Plywood-Common-1-4-in-x-2-ft-x-4-ft-Actual-0-205-in-x-23-75-in-x-47-75-in-225515/206120921
6	http://www.homedepot.com/p/WeatherShield-1-in-x-2-in-x-8-ft-Pressure-Treated-Board-315412/100024161
7	http://www.homedepot.com/p/2-in-x-4-in-x-96-in-Premium-Kiln-Dried-Whitewood-Stud-161640/202091220
8	http://www.homedepot.com/p/2-in-x-6-in-x-8-ft-2-and-Better-Kiln-Dried-Heat-Treated-Spruce-Pine-Fir-Lumber-161713/100037451
9	http://www.homedepot.com/p/Sanded-Plywood-Common-23-32-in-x-2-ft-x-2-ft-Actual-0-703-in-x-23-75-in-x-23-75-in-1502014/202089017
10	http://www.homedepot.com/p/Everbilt-Assorted-Colors-1-8-in-x-50-ft-Para-cord-12715/203602865
11	http://www.homedepot.com/p/Everbilt-Spring-Assortment-Kit-84-Pack-13554/203133714
12	http://www.homedepot.com/p/Everbilt-3-4-in-Zinc-Plated-Corner-Braces-4-Pack-13542/202950157
13	http://www.homedepot.com/p/Simpson-Strong-Tie-18-Gauge-Galvanized-Steel-Angle-A21/100374951
14	http://www.homedepot.com/p/Everbilt-1-1-2-in-Zinc-Plated-Narrow-Utility-Hinge-2-Pack-15396/202034103
15	http://www.homedepot.com/p/Everbilt-1-2-in-x-6-in-Heavy-Duty-Beige-Felt-Strips-9-Pack-49954/300194064
16	https://www.walmart.com/ip/Cap-Barbell-5-Lb-Neoprene-Dumbbell-Promotional/180228101
17	https://www.walmart.com/ip/CAP-Barbell-Neoprene-Dumbbell-Single/
18	http://www.homedepot.com/p/Everbilt-2-in-Zinc-Plated-Mending-Plate-4-Pack-15299/202033910

Figure 10: Bill of Materials

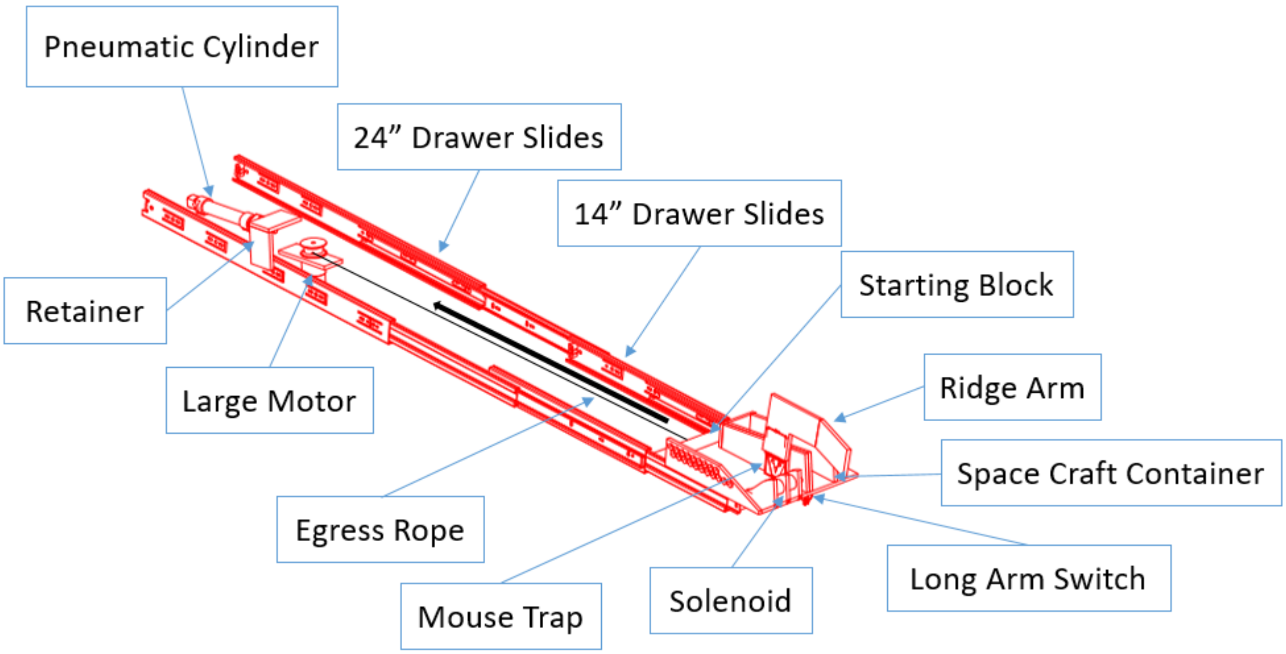


Figure 11: His Airness Mountain Ridge Subsystem

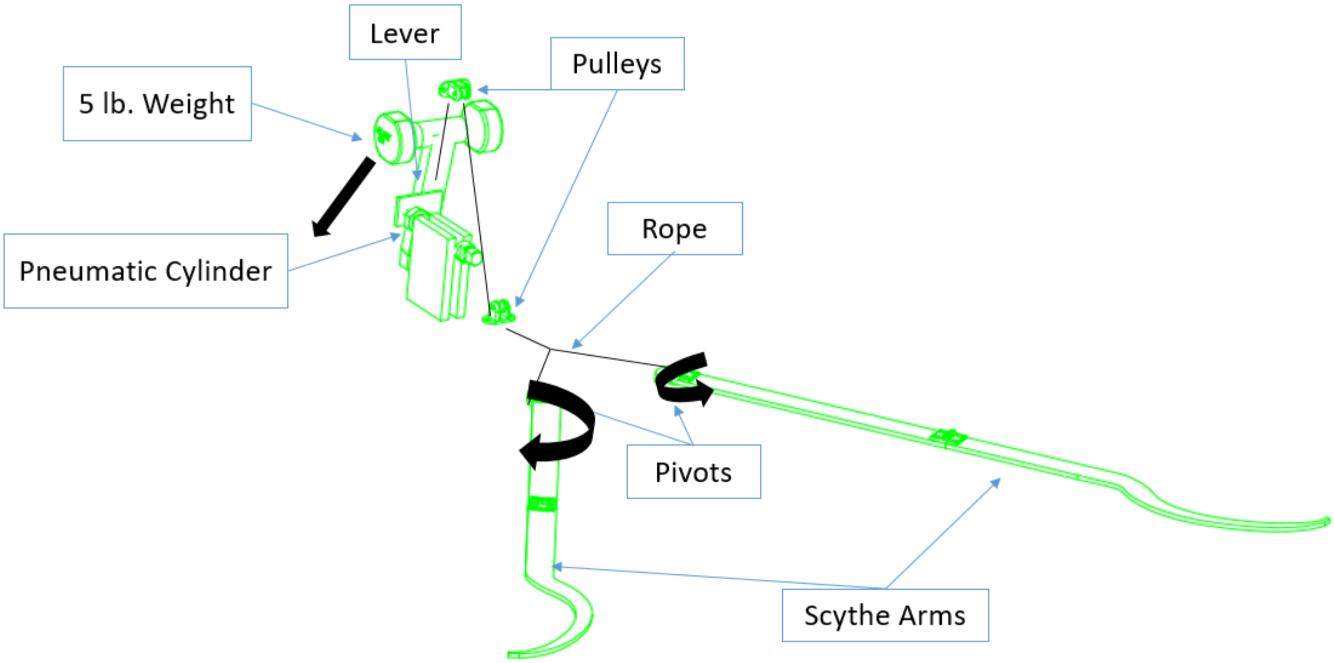


Figure 12: His Airness Pivot Arms Subsystem

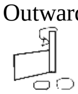
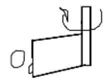
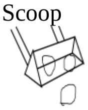
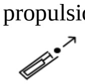
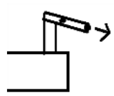
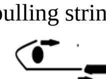
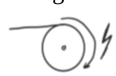
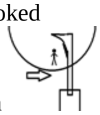
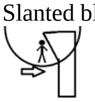
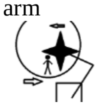
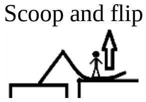
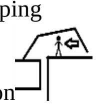
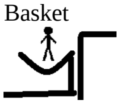
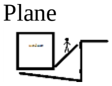
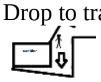
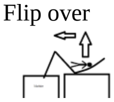
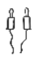
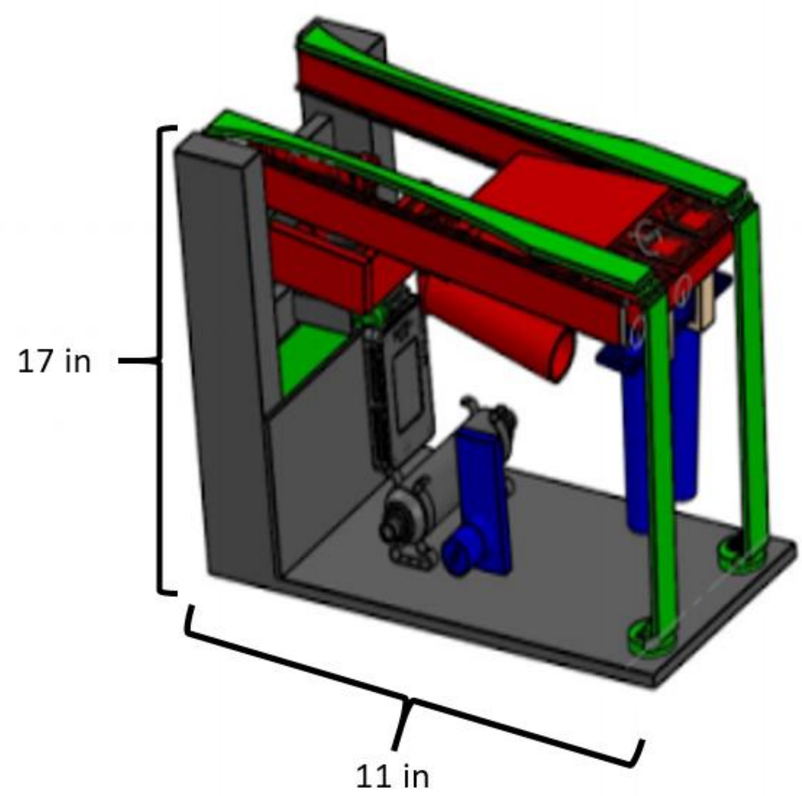
Solution Function	Sol. 1	Sol. 2	Sol. 3	Sol. 4	Sol. 5	Sol. 6
Signal Whimsy	America	Spacex	Superman	Georgia Tech	Batman	
Remove Boulders	Lever Arm 	Sweep Outward 	Sweep Inward 	Scoop 	Rolling Object 	
Collect Supply crates	Mouse Trap Arms 	Motor Arm 	Pulley Arms 	Rover 	Net 	
Detect safe zones	Longarm sensor 	Roller sensor 	Infrared Sensor 	Mousetrap triggered 	Timer 	Ultrasound Sensor 
Deliver spacecraft	Air cylinder propulsion 	Inclined Plane 	Tube roll 	Mousetrap launch 	Solenoid pulling string 	Scissor Extention 
Regress equipment	Hinge retraction 	Pulley Drawer sliders 	Wheels 	Scissor Retract 	String on motor 	
Retrieve Astronauts/ Rovers	Hooked  arm	Slanted block 	Spinning arm 	Scoop and flip 	Swinging lever 	Sweeping  motion
Retain Astronauts/ Rovers	Basket 	Funnel to home 	Inclined Plane 	Drop to track 	Flip over 	
Receive overall start signal	Banana plug 	Timer 				

Figure 13: Morph Chart

Figure 14: The Barkley Boxed view



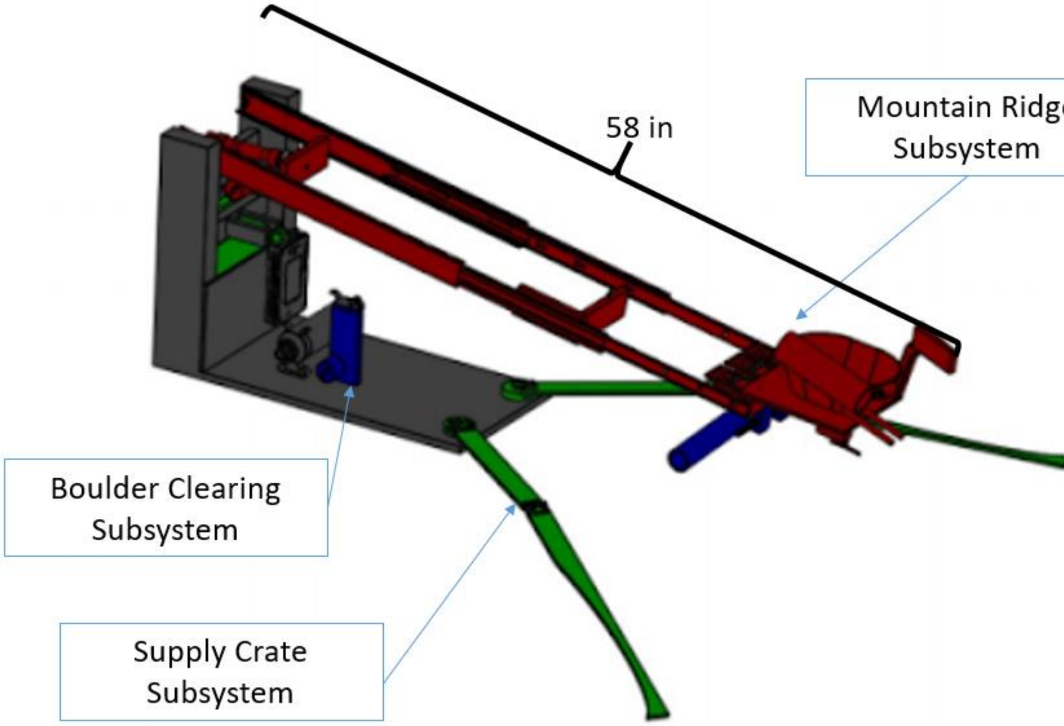


Figure 15: The Barkley Deployed View

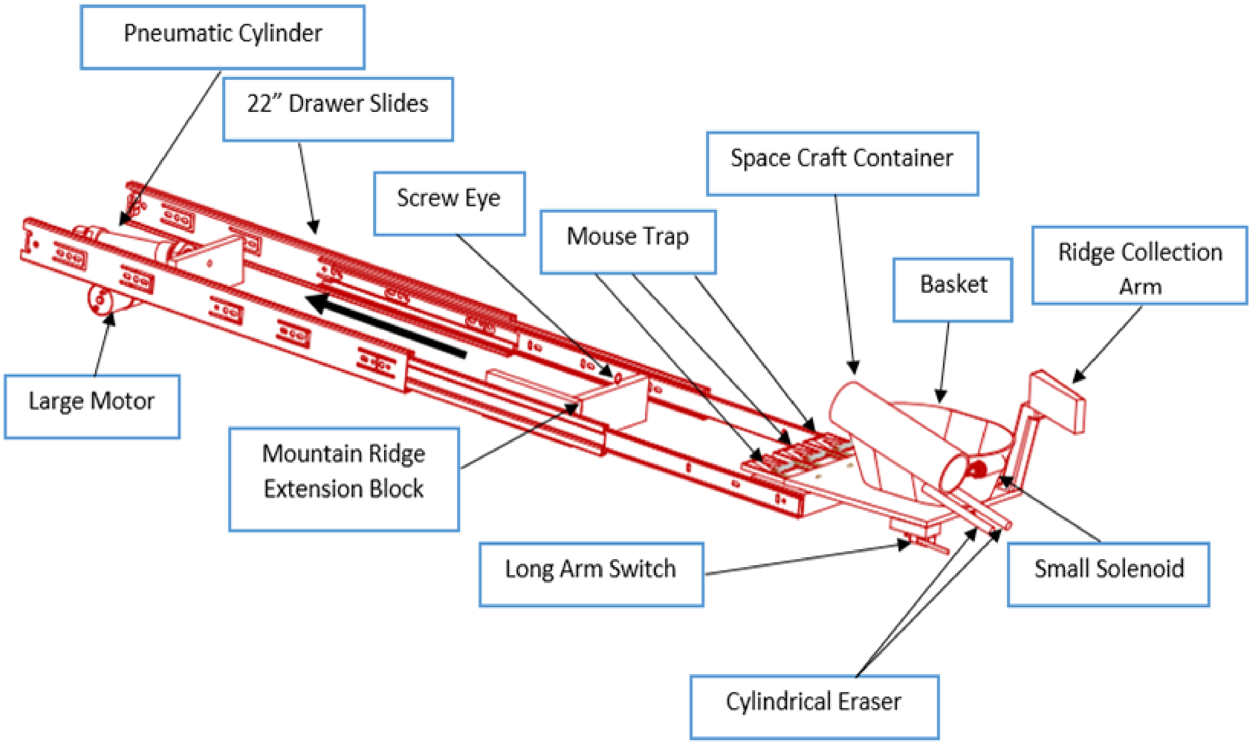


Figure 16: The Barkley Mountain Ridge Assembly

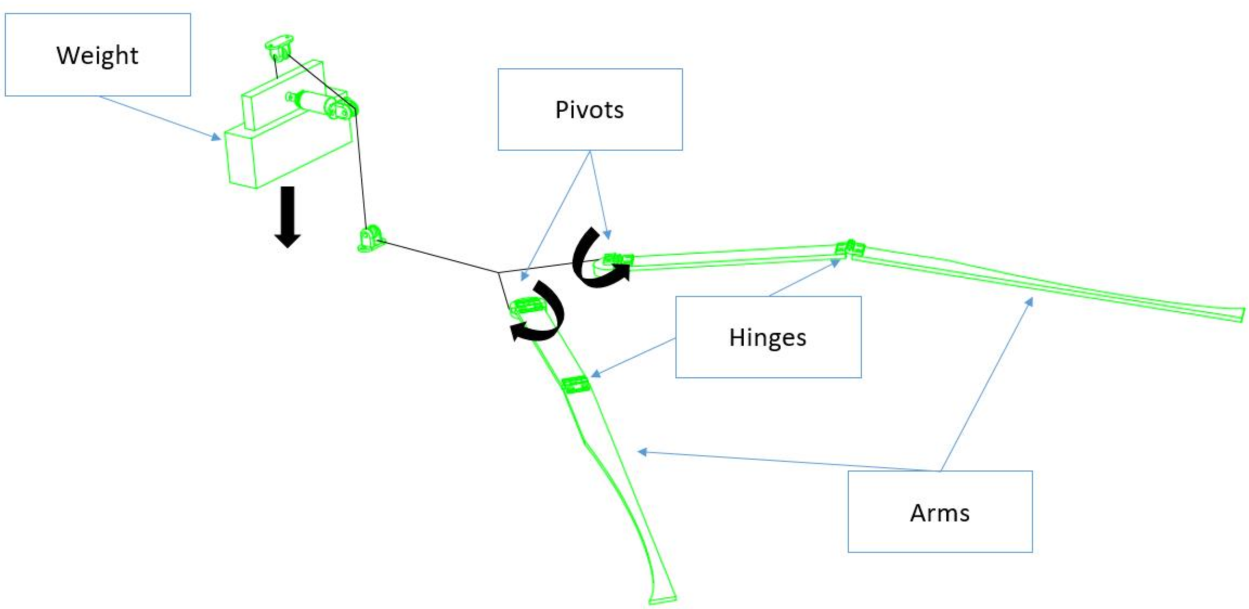


Figure 17: The Barkley Supply Crate Assembly

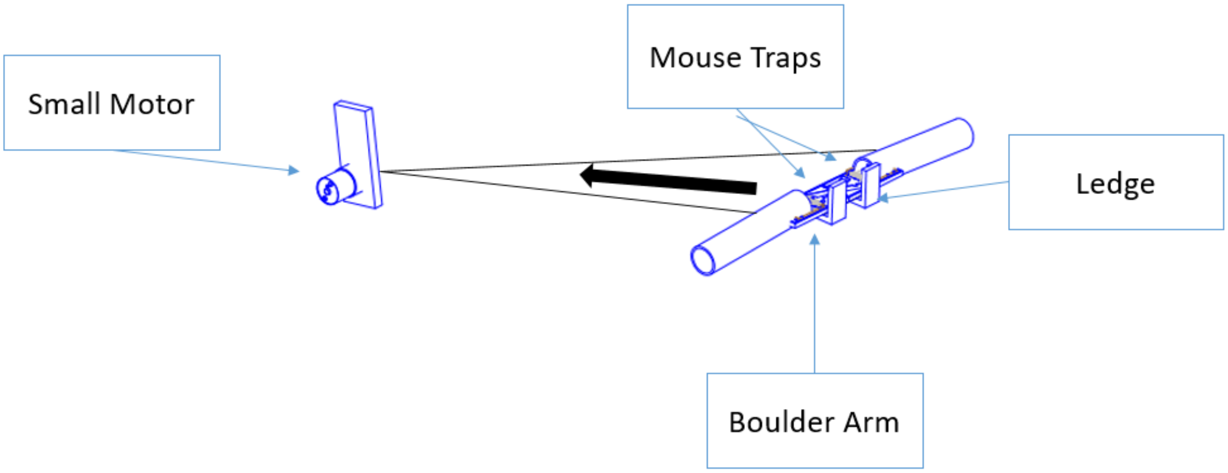


Figure 18: The Barkley Boulder Clearing Assembly

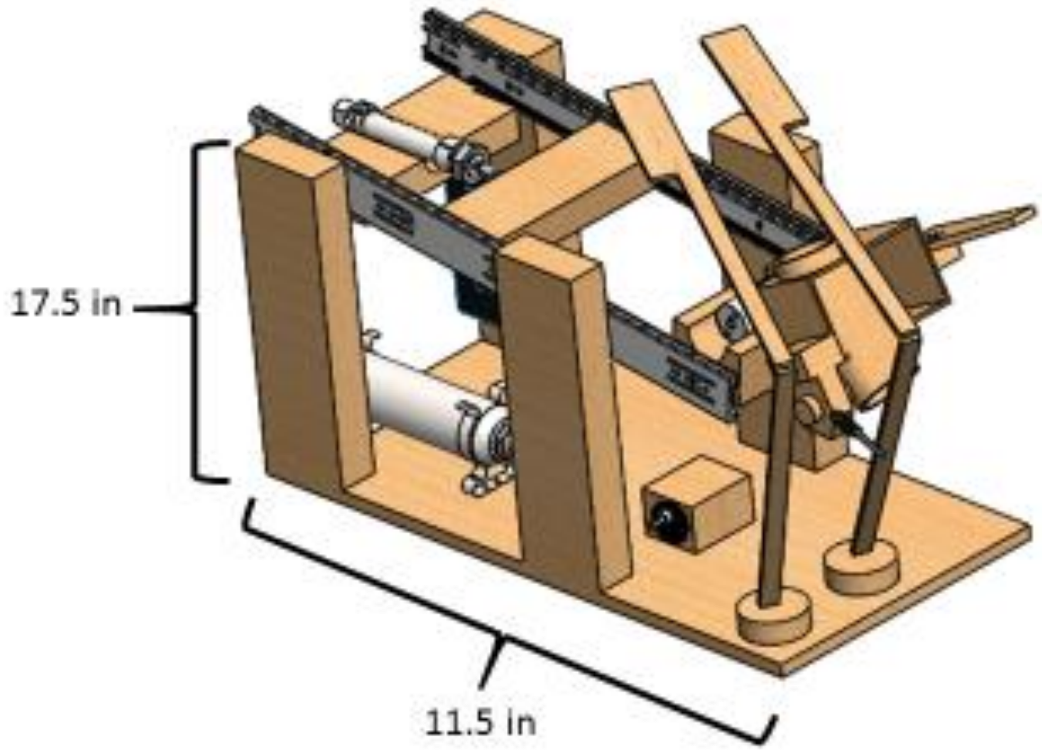


Figure 19: The Bird Collapsed View

\

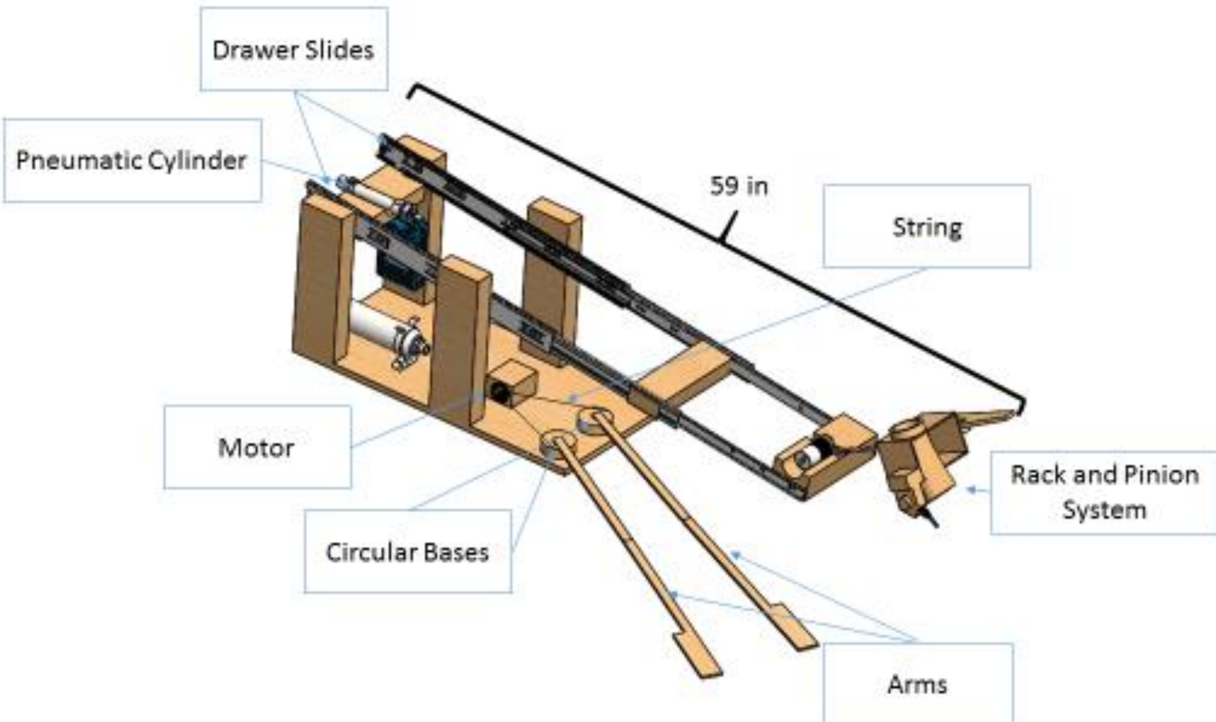


Figure 20: The Bird Deployed View

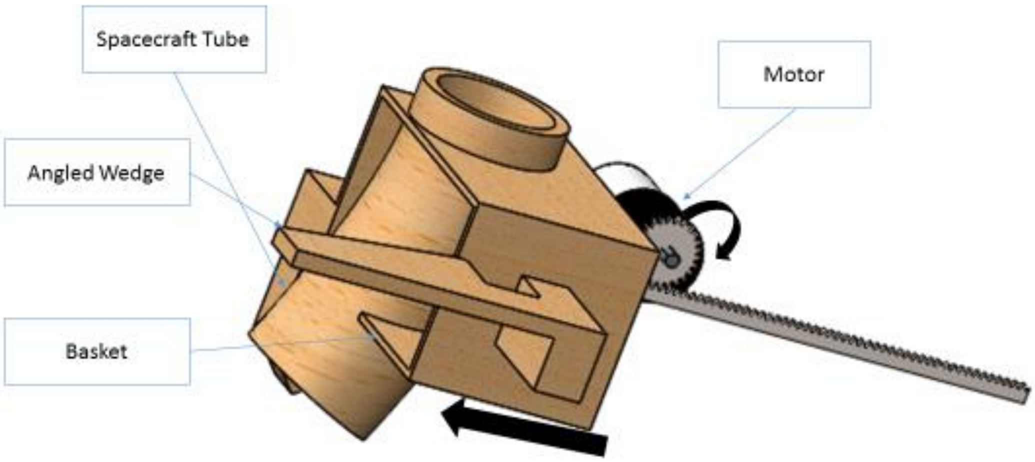


Figure 21: The Bird Rack and Pinion System

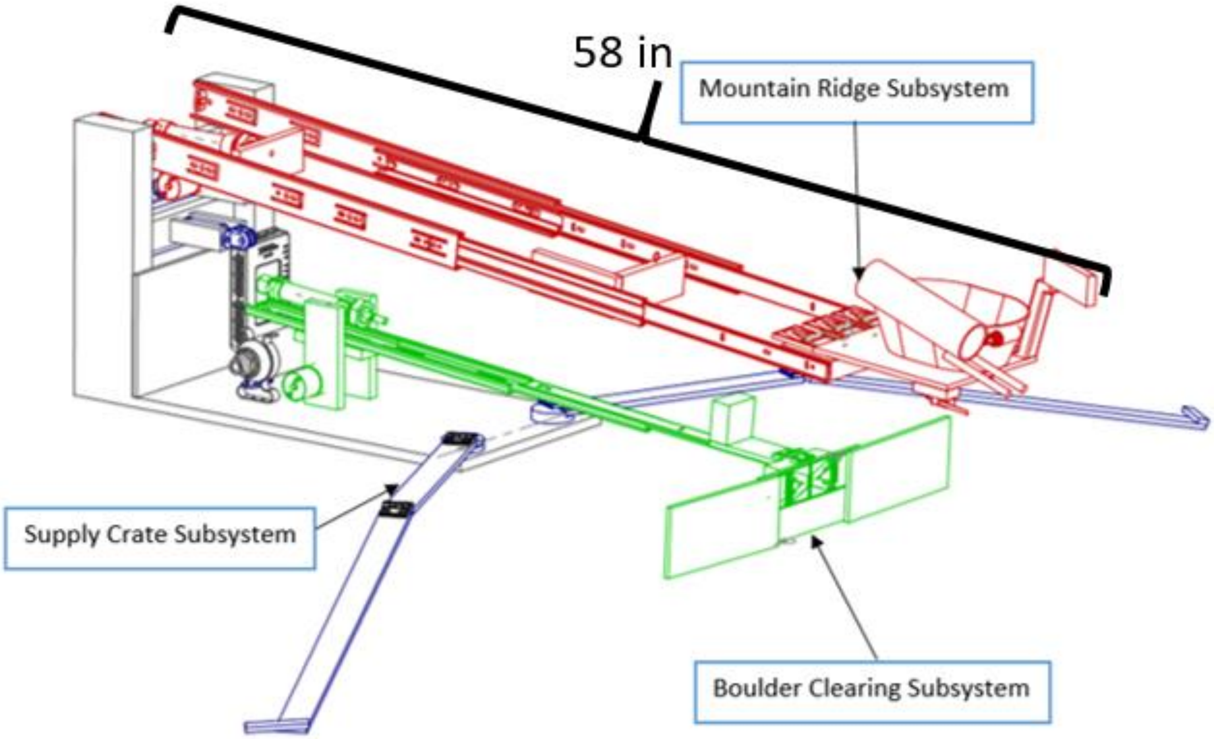


Figure 22: Magic Johnson Deployed View

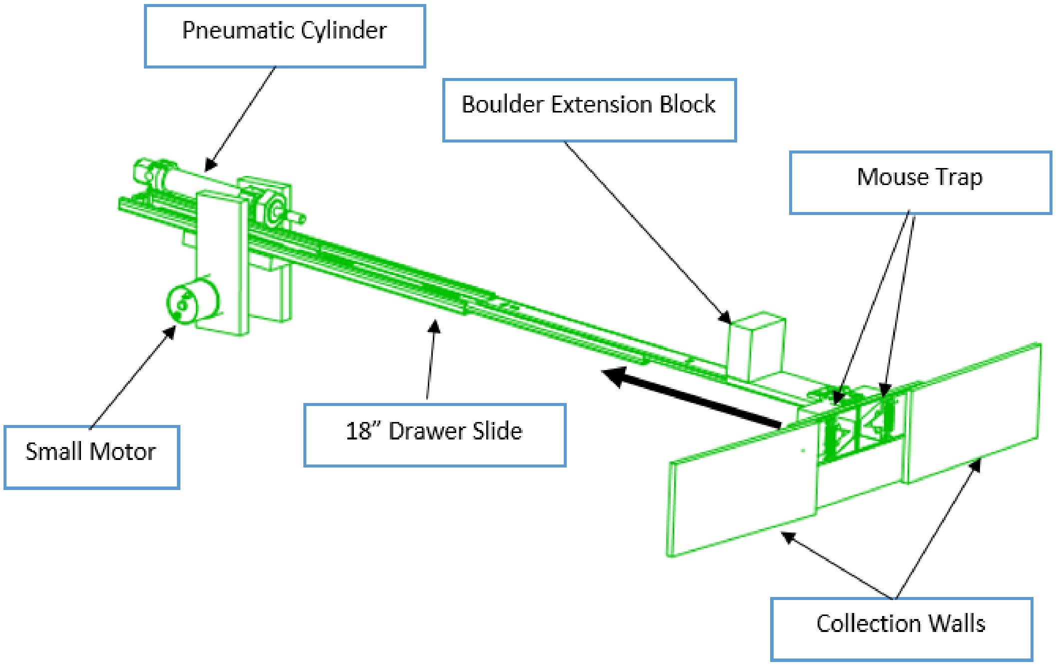


Figure 23. Magic Johnson Boulder Clearing Subsystem

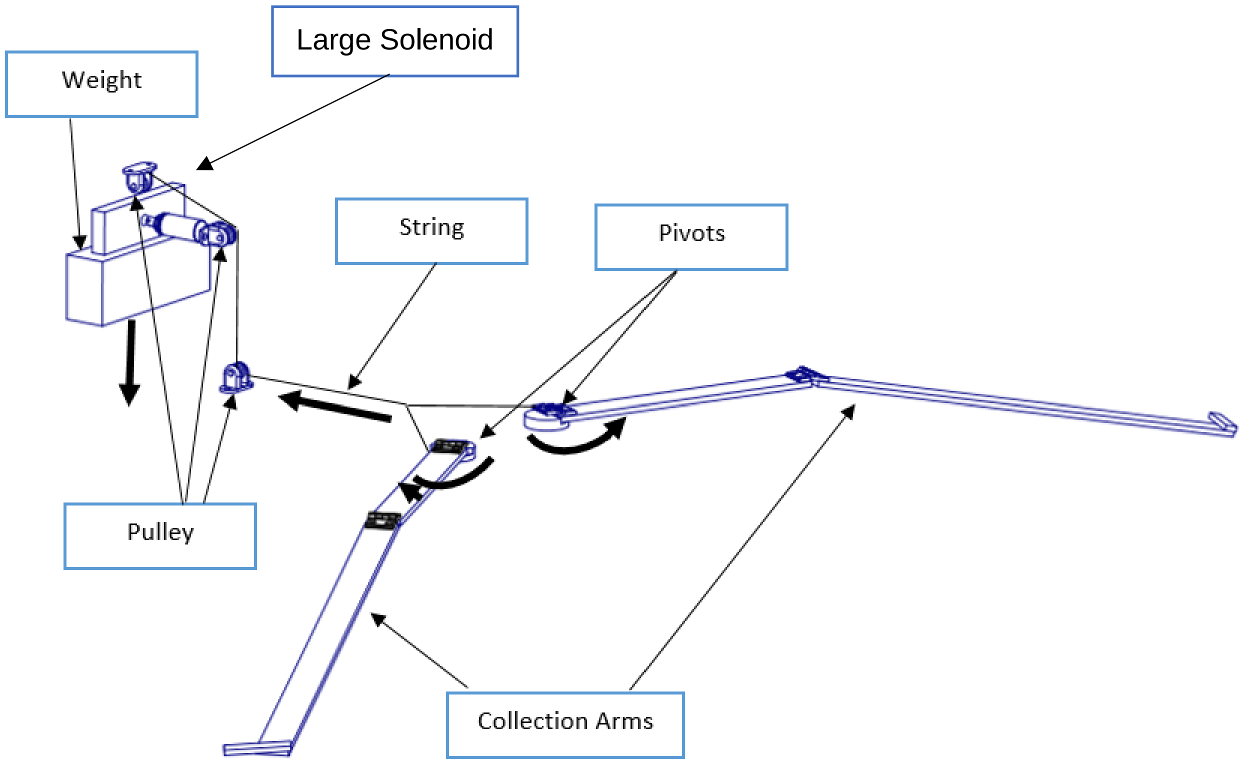


Figure 24: Magic Johnson Supply Crate Subsystem

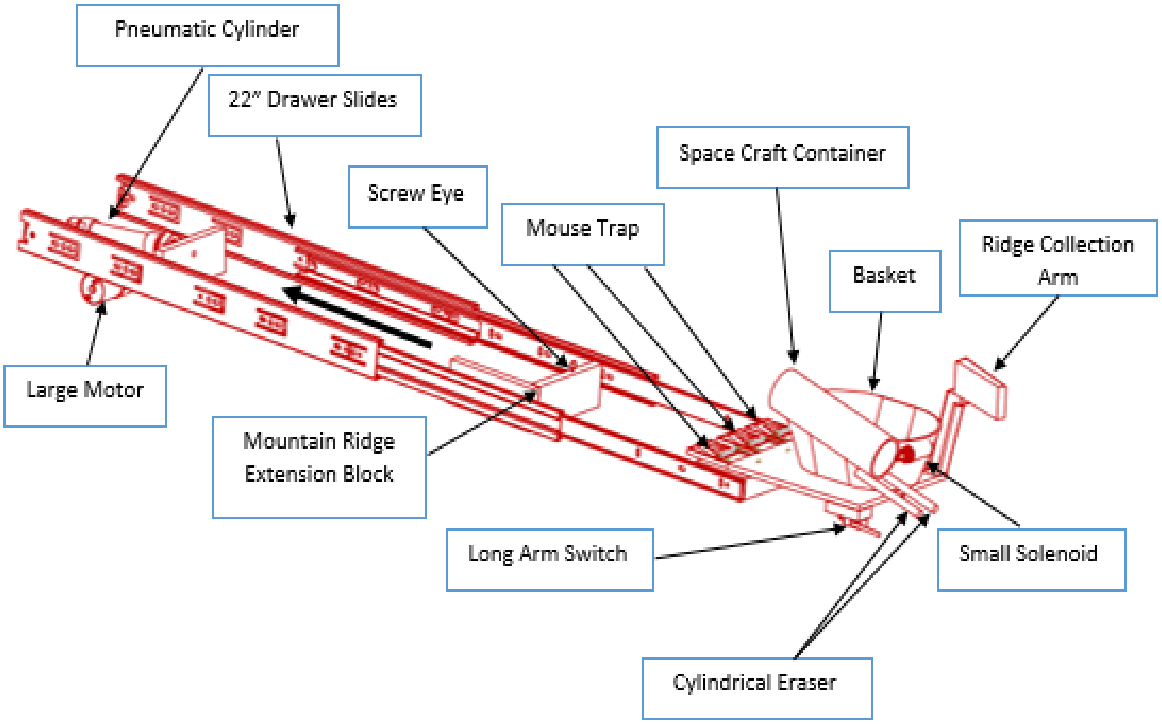


Figure 25: Magic Johnson Mountain Ridge Assembly

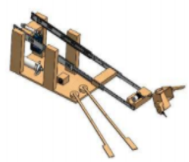
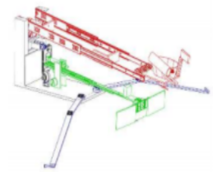
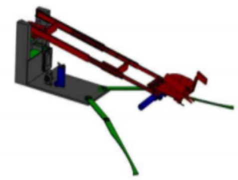
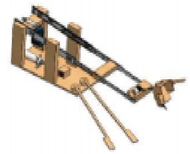
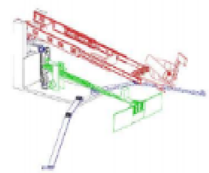
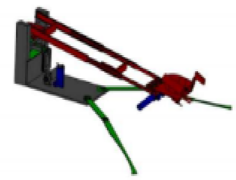
	 The Bird	 The Magic Johnson	 The Barkley	 His Airness
Remove Boulders		+	+	+
Retrieve Supply Crates	D		+	+
Deliver Spacecraft	A		-	
Retrieve Rovers and Astronauts	T	-		
Egress Rescue System	U			
Easily Manueverable	M	-	+	+
Low cost		-		-
Operates under time constraints		+	-	
Easily Reset		-		
Safety of track				+
Sum +		2	3	4
Sum -		4	2	1
Total Score		**-2**	**+1**	**+3**

Figure 26: Pugh Chart

		 The Bird		 The Magic Johnson		 The Barkley		 His Airness	
	Weights	Scores	Weighted Scores	Scores	Weighed Scores	Scores	Weighted Scores	Scores	Weighted Scores
Remove Boulders	6	2	12	3	18	3	18	4	24
Retrieve Supply Crates	8	4	32	4	32	2	16	5	40
Deliver Spacecraft	12	5	60	4	48	3	36	5	60
Retrieve Rovers and Astronauts	14	5	70	4	56	4	56	4	56
Egress Rescue System	10	5	50	5	50	5	50	5	50
Easily Maneuverable	4	4	16	2	8	4	16	4	16
Low Cost	2	3	6	1	2	4	8	3	6
Operates under Time constraints	14	3	42	5	70	2	28	4	56
Speed of Operations	12	5	60	3	36	4	48	5	60
Safety of track	2	5	10	5	10	5	10	4	8
Accuracy in completing tasks	16	3	48	4	64	3	48	5	80
Sum	100	44	406	40	394	39	334	48	456
Fractional Sum			0.812		0.82		0.668		0.88

1 Poor
2 Mediocre
3 Good
4 Excellent
5 Extraordinary

Figure 27: 3rd Level Evaluation Matrix

Table 3: Results

	Points possible per run	Run 1 Points	Run 2 Points	Run 3 points	Run 4	Total Points (3 runs)
Week 5: Supply Crates	80	70	70	60	N/A	200
Week 6: Mountain Ridge	284	15	DQ	DQ	N/A	15
Week 7: Qualifying	364	-8	10	DQ	N/A	2
Final Competition	364	130	60	130	90	N/A

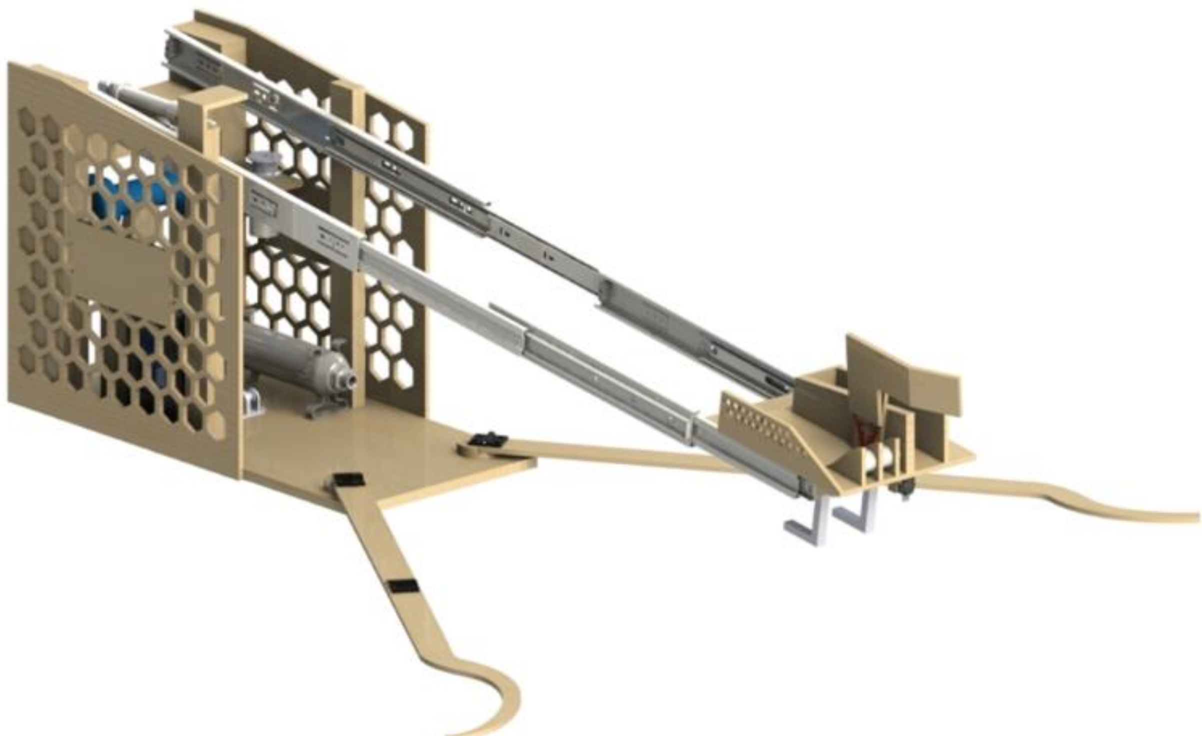


Figure 28: Final Design Render

References

[1] "Ergonomics eTool: Solutions for Electrical Contractors - Materials Handling: Heavy Lifting", Osha.gov, 2017. [Online]. Available: https://www.osha.gov/SLTC/etools/electricalcontractors/materials/heavy.html. [Accessed: 11- Jun- 2017].

[2] "DigiKey Electronics - Electronic Components Distributor", Digikey.com, 2017. [Online]. Available: https://www.digikey.com/. [Accessed: 11- Jun- 2017].

[3] "Anaheim Automation - Your source for Stepper Motor, Brushless DC Motor, DC Motor, and Planetary Gearbox Products", Anaheimautomation.com, 2017. [Online]. Available: http://www.anaheimautomation.com/. [Accessed: 11- Jun- 2017].

[4] "McMaster-Carr", Mcmaster.com, 2017. [Online]. Available: https://www.mcmaster.com/. [Accessed: 11- Jun- 2017].

[5] "Pneumatic & electric automation technology manufacturer | Festo USA", Festo.com, 2017. [Online]. Available: https://www.festo.com/cms/en-us_us/index.htm. [Accessed: 11- Jun- 2017].

[6] "The Design Project: Mission to Mars 2", Georgia Institute of Technology, 2017. [Online]. Available: http://2110.me.gatech.edu/sites/default/files/documents/Big_Project/me2110_summer_2017_studio4_missiontomars_final_0.pdf. [Accessed: 15- Jul- 2017].

[7] "Mechatronics and Pneumatics Kit Manual", Georgia Institute of Technology, 2017. [Online]. Available: http://2110.me.gatech.edu/sites/default/files/documents/Mechatronics/recent_mechatronics_and_pneumatics_kit_manual_160107.pdf. [Accessed: 15- Jul- 2017].

[8]"Steel Drawer Slides with Lever Drawer Release, 22" Closed Length", *Mcmaster.com*, 2017. [Online]. Available: https://www.mcmaster.com/#11435a27/=1886jdi. [Accessed: 23- Jun- 2017].

[9]"BDSG-37-40 - Small DC Motors with Spur Gearboxes", *Anaheimautomation.com*, 2017. [Online]. Available: http://www.anaheimautomation.com/products/brush/dc-gearmotor-item.php?sID=259&serID=6&pt=i&tID=102&cID=46. [Accessed: 23- Jun- 2017].

[10]"Standard cylinder ESNU-20-50-P-A 2D/3D CAD", *Festo.com*, 2017. [Online]. Available: https://www.festo.com/eap/en-us_us/DKI3CAD2/start.do?language=en-us&country=us&PartNo=19268&IDCODE1=ESNU-20-50-P-A. [Accessed: 23- Jun- 2017].

[11]"Air reservoir CRVZS-0.4 2D/3D CAD", *Festo.com*, 2017. [Online]. Available: https://www.festo.com/eap/en-us_us/DKI3CAD2/start.do?language=en-us&country=us&PartNo=160234&IDCODE1=CRVZS-0.4. [Accessed: 25- Jun- 2017].

[12]"NI MYRIO", *My.solidworks.com*, 2017. [Online]. Available: http://my.solidworks.com/reader/3dccparts/catalogid%253D171%2526id%253D557253/ni-myrio. [Accessed: 24- Jun- 2017].

[13] P. Lessard, “Mouse Trap,” GrabCAD - CAD library, 28-Oct-2014. [Online]. Available: https://grabcad.com/library/mouse-trap-4. [Accessed: 12-Jun-2017].