10/24/2019

EML4551-2

Team 514: FSGC – Human Exploration Rover Challenge

Author 1: Tavares L. Butler; Author 2: Phillip M. Dimacali ; Author 3: Jessica T. Meeker ; Author 4: Lazaro A. Rodriguez ; Author 5: Jerald T. Yee

FAMU-FSU College of Engineering 2525 Pottsdamer St. Tallahassee, FL. 32310

Abstract

The abstract is a concise statement of the significant contents of your project. The abstract should be one paragraph of between 150 and 500 words. The abstract is not indents.

Keywords: list 3 to 5 keywords that describe your project.

Disclaimer

Your sponsor may require a disclaimer on the report. Especially if it is a government sponsored project or confidential project. If a disclaimer is not required delete this section.

Acknowledgement

These remarks thanks those that helped you complete your senior design project. Especially those who have sponsored the project, provided mentorship advice, and materials. 4

- Paragraph 1 thank sponsor!
- Paragraph 2 thank advisors.
- Paragraph 3 thank those that provided you materials and resources.
- Paragraph 4 thank anyone else who helped you.

Table of Contents

List of Tables

List of Figures

Notation

AHP	Analytical Hierarchy Process
CAD	Computer Aided Design
FSGC	Florida Space Grant Consortium
HoQ	House of Quality
NASA	National Aeronautics and Space Administration

Chapter One: EML 4551C

1.1 Project Scope

Project Description:

A human-powered vehicle capable of safely and quickly transporting two individuals through regolith terrain, particularly, considering guidelines set by the NASA Human Rover Exploration Challenge.

Key Goals:

The key goals of this project are as follows:

- Drivetrain provides necessary power
- Rover Successfully traverses regolith terrain
- Wheel assembly is originally designed and manufactured
- Drivetrain is originally designed and manufactured
- Rover components are structurally sound
- Misalignments and vibrations are minimized
- Rover is capable and competitive
- Rover Pilots are kept safe

Markets:

The markets surrounding the FSGC – Human Exploration Rover are hierarchical. The primary, immediate markets consist of organizations performing space exploration and those who require a vehicle to traverse regolith terrain. Secondary markets may include hobbyists, outdoorsmen, and smaller organizations that require a capable off-road vehicle such as ski resorts and remote nature parks.

Assumptions:

The following assumptions are made regarding the Exploration Rover:

- Vehicle will be designed, specified, and verified using earth's physical specifications.
- Drivetrain will be entirely human-powered
- Rover pilots will control steering, propulsion, and braking
- Test terrain is regolith
- Two individuals will pilot rover
- Design will abide by the 2020 NASA Human Exploration Rover Challenge Guidebook

Stakeholders:

The stakeholders who hold interest and will ultimately have an impact regarding the outcome of this project are tabulated below as well as their role in decision making and financial contributions.

Table 1.1.1
Stakeholders

Stakeholder	**Financial**	**Decision Maker**
Shayne McConomy	✔	✔
Chiang Shih	✔	✔
Keith Larson		✔
FAMU-FSU College of Engineering	✔	✔
NASA		✔

1.2 Customer Needs

The goal of our project is to design a vehicle capable of competing in the NASA Human Exploration Rover Challenge. The challenge consists of an obstacle course imitating the Martian surface along with tasked to be completed during the course. The competition presents a unique challenge for the customer needs as they are primarily derived from the competition guidebook and input from our Sponsor/Advisor. The guidebook gives a total points breakdown, and from this breakdown the team decides on which obstacles and tasks to attempt to maximize total points earned. The guidebook is only a list of standards that must be met, and the team will decide on the best route to maximize point totals that align with the given customer needs.

Table 2.2.1
Customer Needs

Customer Statement	**Interpreted Need**
A rover with riders in position ready to ride must have no less than 12 inches (30.48 cm) ground clearance.	All components in contact with the rider are at least 12 inches from the ground to its lowest point (seats, pedals, handles, etc.).
A U.S., national or institutional flag must be visible from the front, the side or the rear.	The vehicle displays a U.S. national flag in the correct orientation.
Task materials must be unique to each rover and have the team number marked on each item. Task materials may not be shared with other teams including those from the same institution.	Task materials are clearly labeled and specified for each team.
Teams will be awarded 1 point per task for having the proper tools for each task that they plan to attempt. Maximum total is 5 points.	The proper tool will be present for each respective task.
Failure to provide robust, practical seat restraints prohibits course participation.	The vehicle drivers are secure and safe during operation.
All sharp edges and protrusions must be	The vehicle possesses rounded edges.

eliminated.	
Specific personal protective equipment is required prior to any team being allowed to compete on the course. NOTE: All drivers must wear a helmet the entire time they are racing. There are no exceptions. Only commercially manufactured protective headgear is accepted.	Vehicle drivers are provided eye-protection, commercially available helmets, full-fingered gloves, long sleeved shirts, pants, socks, and closed-toed shoes.
Each team will be required to develop a signal system between the two drivers to ensure hands are clear before proceeding.	Vehicle drivers use an originally developed communication system to ensure driver safety, particularly regarding the position of their hands during operation.
Teams should be strategic in choosing the obstacles and tasks to complete to maximize point value.	The vehicle addresses obstacles and tasks stated in the NASA Human Exploration Rover Challenge Guidebook.
Teams have a total of 8:00 minutes to complete each excursion. The team must return to home base or the finish line in 8:00 minutes or less to be eligible for competition prizes. The event clock stops when the rover crosses the finish line.	The vehicle is capable of quick and agile maneuvers.
For the attempt to be considered successful both drivers must be on the rover prior. An attempt is deemed unsuccessful when the rover veers off. Exception: If the obstacle is associated with a task that requires the driver to disembark will not be penalized for an unsuccessful attempt of the obstacle.	Both drivers are in the vehicle during approach and attempt at completing course obstacles.
Rovers that judges anticipate will affect the course time of another rover may be removed from the course at the judge's discretion.	Vehicle functions properly during operation.
Teams conducting one or more tasks will demonstrate task collections and completions for judging.	The drivers abide by the guidebook regarding task attempt and completion.
Propulsion System: Rovers must be human-powered. Energy storage devices, such as	Human input power will be the sole energy source for the rover.

springs, flywheels, batteries or others are not allowed to be used as part of the drive train.	
Rover performance: Teams should expect their rover to be capable of traversing hills up to 5 feet (~1.5 meter) high and path ways inclined up to30 degrees in their direction of travel and transverse to the direction of travel. Wheels and drive trains should be designed for both speed and the ability to perform on the difficult terrain. A 15-foot(4.57meter) or less turning radius is also necessary.	The vehicle can climb steep inclines and has a turning radius of 15 feet or less.
Vehicle Dynamics: For safety reasons, it is recommended that the center of gravity of the vehicle plus rover drivers be low enough to safely handle slopes of 30 degrees front-to-back and side-to-side.	The vehicle, containing riders, has a low and safe center of gravity.
We encourage you to avoid using bike chains, which have proven to be inadequate in past races.	The vehicle utilizes an innovative and effective drivetrain system.
Each team is required to compete for the Technology Challenge Award, which once again concentrates on wheel design and fabrication. Rover wheels will encounter hard and regolith-like surfaces. Soft surfaces may include sand and small pebbles. Hard surfaces may include simulated rock outcroppings, fissures or cracks up to 5 inches (~13 cm) wide, and slopes up to 30 degrees	The wheel assembly is an original design.
The only commercial items that may be used in the fabrication of the rover wheels are the hubs containing bearings or bushings. Strips or other portions of commercial tires may not be used on rovers competing in the Challenge.	The drivetrain allows riders to stand idle while the wheels are spinning.
Vehicles not constructed by the entering team are not acceptable. Student teams are expected to design, construct and test their own rovers.	The vehicle an original design.
Pushing the rover with a pole or other	Propulsion of the vehicle is through

implement is not allowed. A driver's use of his or her hands on the wheels (as with a wheelchair) to rock or otherwise facilitate moving the vehicle is permitted.	transmission of power to the wheels.
All tools associated with tasks that are on the rover at the start of an excursion must be carried on the rover throughout the excursion except for the instrumentation package, which is left at the task site, if that task is attempted. This tool must remain on the rover throughout the excursion if the associated task is not attempted.	Task tools are stored on the vehicle during the entire excursion.
All tasks and obstacles are attempted.	Vehicle can attempt every task and obstacle
A tasks and obstacles of similar events are completed for full points.	Vehicle can complete tasks.
Innovative	Vehicle exhibits new and unique characteristics original to its design.

From Table 1.2.1 above, a portion of the customer needs are requirements that need to be met to be eligible for competition participation. The majority of the customer needs have to do with point allocation and distribution amongst tasks and obstacles. Obstacles and tasks to be attempted will be discussed amongst team members along with the sponsors to ensure optimal point accumulation and objective preparedness. Each customer need that relates to competition eligibility will be met, along with every attempted task or obstacle will be attempted for maximum points.

The table puts engineering interpretations of needs established by the guidebook, sponsors, and advisors. The interpreted customer needs are significant in the future implementation of the functional decomposition. These interpretations are important because it bridges the gap between what the customer wants versus what the product is going to do. Not all needs can reasonably be met, so a separation into engineering interpretations allows for more in-depth methods to highlight key features delivering the best product possible. These interpretations will also be utilized later in the concept generation and concept selection phases, as each need dictates an aspect of the rover design.

1.3 Functional Decomposition

From the synthesized customer needs and a knowledge of preexisting human powered vehicles, the scope of what the rover needs to be able to perform can be determined. This scope is then decomposed into its systems and subsequent functions. The three major systems are the translational motion system, safety system, and stability system. The major systems are further decomposed and displayed in Figure 1.3.1 along with their accompanying functions.

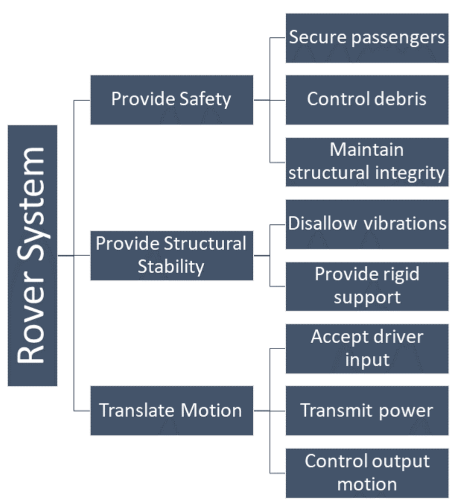


Figure 1.3.1 Device, System, Subsystem Functional Decomposition Flowchart

Providing safety, structural stability and translating motion are all major functions defined at the system level for what the rover must do, but each system can be further decomposed into what each respective function will do fundamentally. Figures 1.3.2, 1.3.3, and 1.3.4 display the system level functional decompositions and their subsequent decompositions.

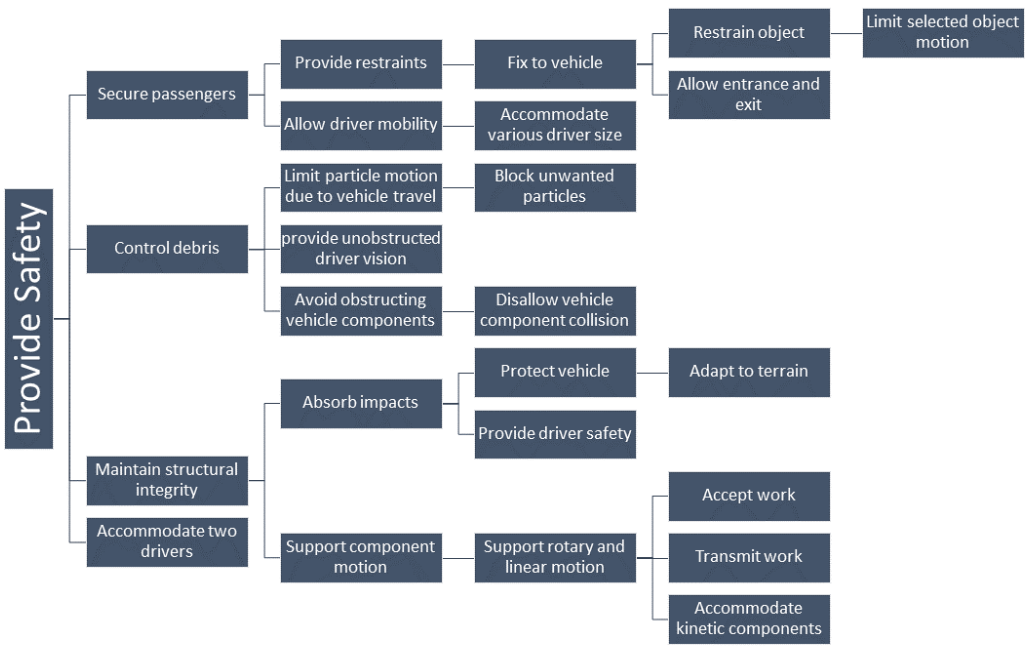


Figure 2.3.2 Provide safety System Functional Decomposition

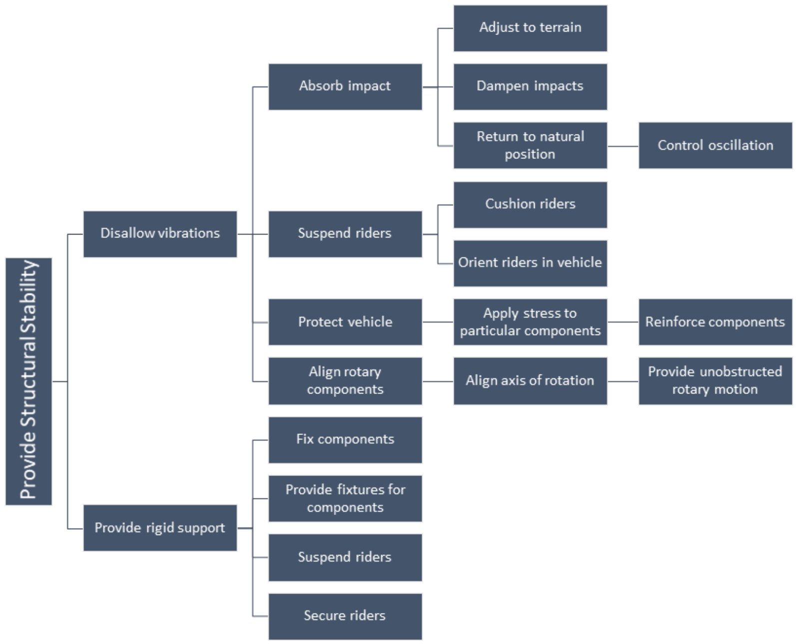


Figure 3.3.3 Provide Structural Stability Functional Decomposition Flowchart

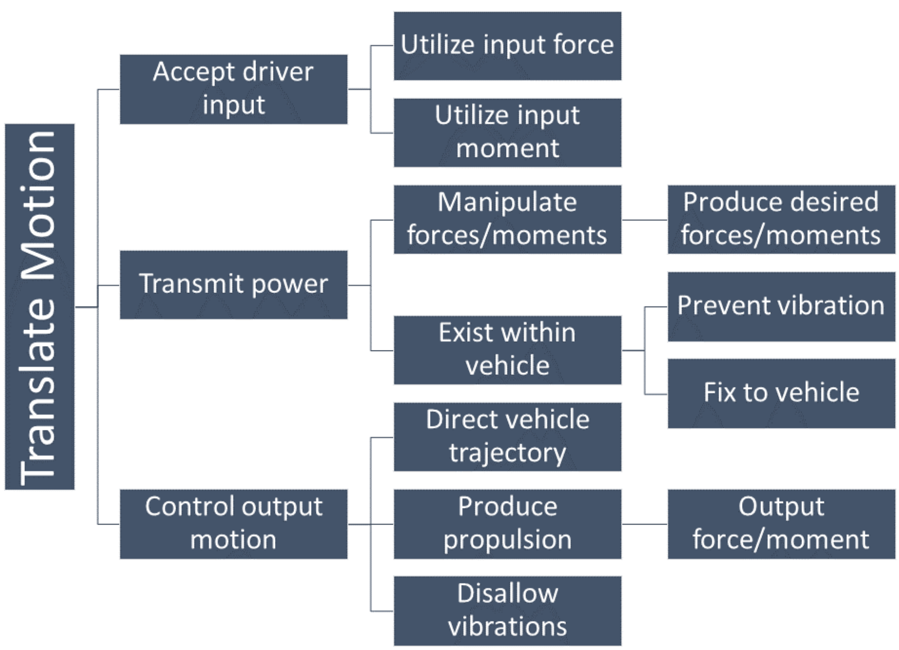


Figure 4.3.4 Translate Motion System Functional Decomposition Flowchart

Figure 1.3.5 displays the project functional decomposition; the system level functions and subsequent decomposed functions are compiled into a single chart and are displayed from top to bottom.

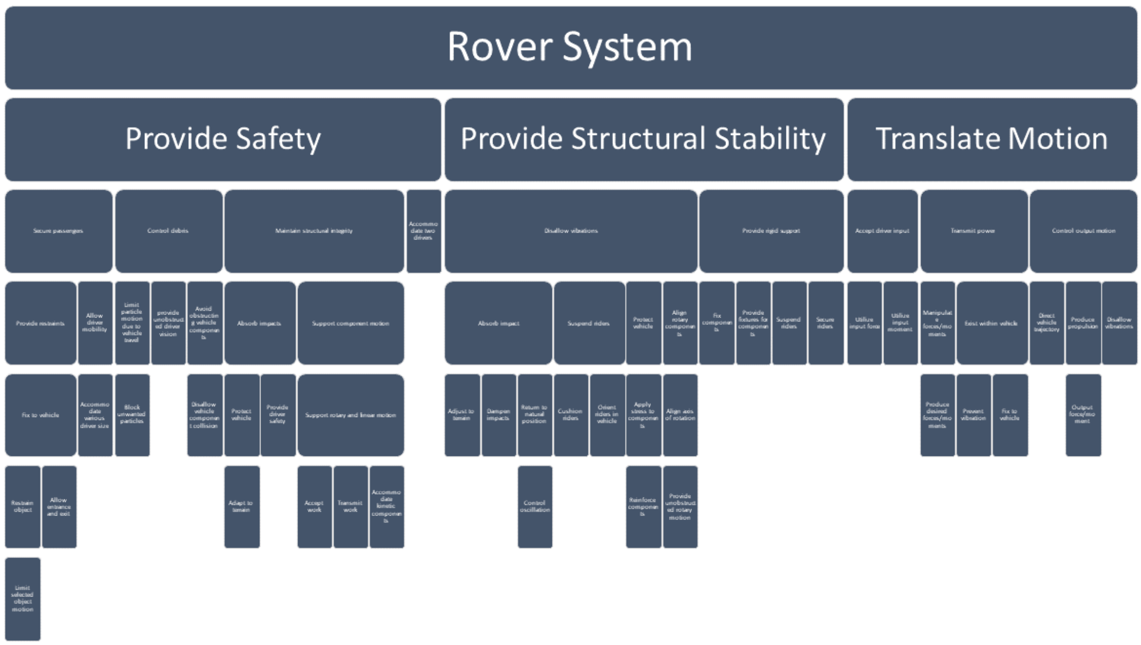


Figure 5.3.5 Complete Rover Functional Decomposition Flowchart

Explanation of Results

Functions, decomposed to the fundamental physical description, aids the designer with fulfilling system requirements and producing innovative concepts. The functions at the system level, provide safety, provide structural stability, and translate motion, represent systems that will exist in the device level. Consequently, further decomposed functions at the subsystem and further levels, represent required outcomes at the system level which the function is describing.

Connection to Systems

Systems can be prioritized; providing safety and providing structural stability are at highest priority because the respective system requirements are strictly according to competition rules. Our top systems can then be separated by our project goal of creating a human powered vehicle that follows the NASA Human Rover Exploration Challenge guidebook. Systems are prioritized by the presence of mission-critical functions, within their respective decompositions, and requirements established by competition rules. Resultantly, our priority, in respective order, is safety, structural stability, and translation of motion. The prioritization of systems will aid in designing an effective rover which fulfills fundamental functions while abiding by competition guidelines.

Smart Integration

It was observed that functions at the most decomposed levels, first and second from the bottom, reoccurred within the three system level functions, provide safety, provide structural stability, translate motion. The following figures exhibits the recurring functions color coded to corresponding the recurring function groups; the recurring function groups are vibration control (green), structural (blue), power transmission (purple).

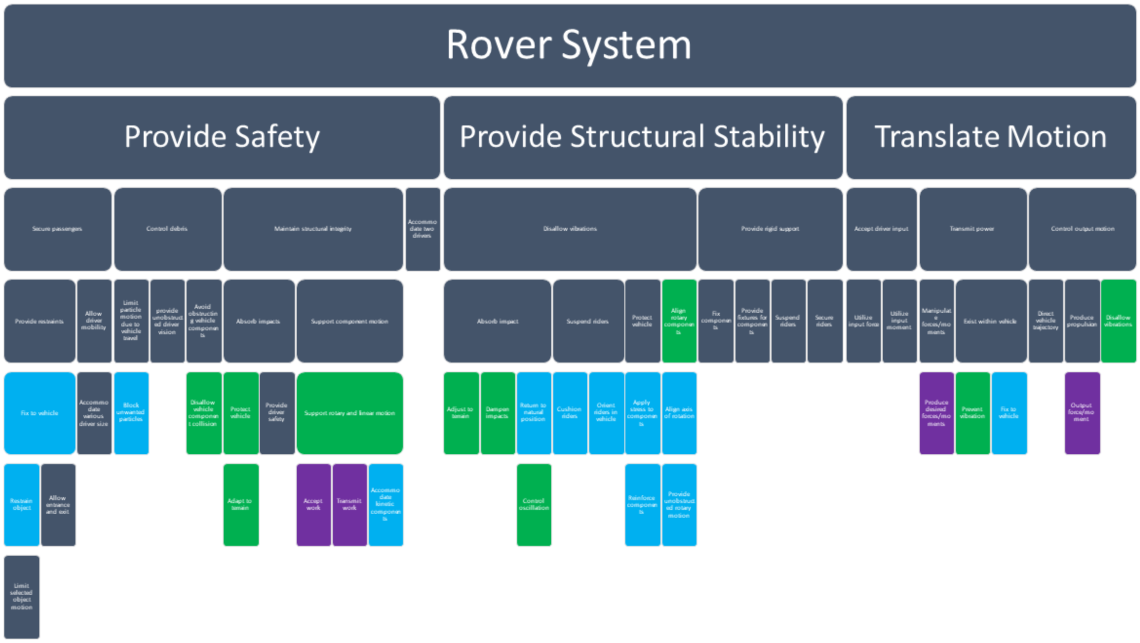


Figure 6.3.6 Cross-Referenced Rover Functional Decomposition Flowchart

The respective color of the decomposed functions represent opportunity to accomplish several functions with a single designed component. Table 1.3.1 displays the function groups (columns) and the fundamental functions (rows); fundamental functions represent potential device systems; “provide safety” corresponding to a safety system, etc. Functions that reside in the same function group, vibration control, for example, are present across differing fundamental functions which presents opportunity to innovate and optimize. For example, functions within vibration control function group are present across the fundamental functions; a component may be designed to accomplish vibration control as well as satisfy the requirements for the fundamental function. This concept of functional cross sub-system relations will be utilized during concept generation and selection in order to produce an optimized device.

Table 3.3.1
Functional Cross Reference Table

	Recurring Function Groups		
	Vibration Control	Structural	Power Transmission
Provide Safety	▪ Disallow vehicle component collision ▪ Protect Vehicle ▪ Adapt To Terrain ▪ Support rotary and linear motion	▪ Fix to vehicle ▪ Restrain object ▪ Block unwanted particles ▪ Accommodate kinetic components	▪ Accept Work ▪ Transmit work
Provide Structural Stability	▪ Adjust to terrain ▪ Dampen impacts ▪ Control oscillations ▪ Align rotary components	▪ Return to natural position ▪ Cushion riders ▪ Orient riders in vehicles ▪ Apply stress to components ▪ Align axis of rotation ▪ Reinforce components ▪ Provide unobstructed rotary motion	
Translate Motion	▪ Prevent Vibration ▪ Disallow Vibrations	▪ Fix to object	▪ Produce desired forces/moments ▪ Output force/moments

Action and Outcome

Additionally, the fundamental functions of, provide safety, provide structural stability, and translate motion can be generalized by describing the systems they represent. Table 1.3.2 displays the fundamental functions and the expected outcome of the system that they represent.

Table 4.3.2
Device Action and Outcome Table

Function/System	Vibration Control	Structural	Power Transmission
Expected Actions and Outcomes	• Dampen impacts • Control oscillations • Maintain axis alignment for rotary	• Suspend riders to required height • Withstand deformation • Secure and protect riders	• Accept input forces/moments • Manipulate forces/moments • Output forces/moments

	components	• Accommodate kinetic vehicle components	

The expectations, regarding functions and outputs, of the Rover are understood results of the figures and tables. The Rover must accomplish the three fundamental functions, provide safety, provide structural stability, and translate motion by ultimately fulfilling the most decomposed functions. In general, the rover must achieve the expected actions and outcomes displayed in table 1.3.2. The newfound understanding of functional requirements will be utilized in generating useful concepts and consequently selecting a concept for research and development.

1.4 Target Summary

The functions are required of the rover in order to meet the project objective. Targets are assigned to each function and associated with a metric to provide a method for testing and validation. The targets presented in Table 1.4.1 were produced by interpreting the associated customer need and using the team's discretion to decide which point tier to attempt each obstacle/task at. Each concepts ability to accomplish the targets from Table 1.4.1 will assist the team in the concept selection phase as each target needs to be met in order to achieve the project objective.

Derivation of Targets

Using the customer needs primarily derived from the NASA Human Exploration Rover Challenge 2020 Guidebook the targets could be formed. Each target is associated with a specific competition guideline or relates to the desired general performance specifications. There are certain mission-critical targets that will be elaborated on in the following section. The guidebook outlines specific criteria in which both the team and the produced rover must adhere to in order to compete in the competition.

Table 5.4.1
Functional Targets and Metrics

Function	Metric	Target
Restrain Object	Amount of fixture points	4-point restraints
Limit selected object motion	Mobility allowed	Extremities
Allow entrance and exit	Time	20 seconds
Allow driver mobility	Mobility allowed	Extremities
Accommodate various driver sizes	Height, weight	5’0” to 6’4” Maximum weight capacity 400 lbs total
Limit particle motion due to vehicle travel	Angle of protection	180 degrees
Provide unobstructed driver vision	Angle of vision	360 degrees
Avoid obstructing vehicle components	Clearance	At least 1 inch
Disallow vehicle component collision	Clearance	At least 1 inch
Absorb impacts	Suspension travel	7 inches
Protect vehicle	Suspension travel	7 inches

Support rotary and linear motion	Factor of safety Length of misalignment	n = 2 < 0.01 inches
Accept work	Type of input	Pedal power Hydraulic braking Mechanical steering
Transmit work	Type of output	Torque to wheels Orientating steering system
Accommodate kinetic components	Types of bearing, gear, sprocket, chain, etc. fitments	ANSI, AGMA, SAE standard fits
Adjust to terrain	Suspension Travel	7 inches
Dampen impacts	Suspension type	Coil spring & damper
Return to natural position	Rider component height	14 inches
Control oscillation	Suspension type	Coil spring & damper
Suspend riders	Rider component height	14 inches
Cushion riders	Rider approval	100% approval
Orient riders in vehicle	Center of gravity	Relatively low
Apply stress to components	Type of suspension	Long-travel, coil spring & damper
Reinforce components	Factor of safety	2
Align rotary components	Number of shaft supports	2
Align axis of rotation	Length of misalignment	< 0.01 inches

Provide unobstructed rotary motion	Clearance	1 inch
Fix components	Factor of Safety	2
Provide fixtures for components	Type of fixing	Through bolt
Suspend riders	Rider Component height	14 inches
Secure riders	Number of restraint fixtures	4
Utilize input force	Turning radius Type of brakes	15 foot hydraulic
Utilize input moment	Type of transmission	Variable torque
Exist within vehicle	Type of transmission	Concealed, recessed components
Prevent vibration	Length of misalignment	< 0.01 inches
Fix to vehicle	Type of mate	Weld, through bolt
Direct vehicle trajectory	Turning radius	15 feet
Produce propulsion	Type of transmission	Variable torque

Table 6.4.2
Additional Targets and Metrics

Metric	Target
Unloaded Weight	200 lbs.
Drivetrain Torque ratio	Variable
Total Cost of Vehicle	< $2000
Unassembled cubic volume	48 square inches

Critical Targets and Validation

Targets that must be fulfilled in order to compete along with other targets that heavily impact overall design are considered to be mission-critical. These targets will have the greatest affect during concept selection phase of our project process. Table 1.4.3 displays these mission-critical targets, along with the validation method and the necessary resources required.

Table 7.4.3
Mission-Critical Targets

Target	Validation	Tools Necessary
Driver mobility limited to the extremities	Having the driving physical sit in the seat and adjust restraints accordingly	Measuring equipment and the assembled restraint system
5’0” to 6’4” Height accommodation Maximum weight capacity 400 lbs. total	Take measurements of individuals and test through 3D modeling	Measuring equipment and 3D modeling software
Pedal power	Physical tests:	For a physical test, we need

Hydraulic braking Mechanical steering	I.e. normal brake testing (pedaling to a certain speed and breaking, then measuring the distance)	the built components of the HPV. Also, 3D modeling software to test design before the build.
Torque to wheels Orientating steering system	3D modeling and physical test once the vehicle is built.	3D modeling software and physical components. Measuring equipment for torque test.
14-inch rider-related component clearance	Test through measurement and 3D modeling. We'll design to make suspension adjustable to enable additional height adjustments.	3D modeling software and measuring equipment
15 foot turning radius	Test through measurement of turning radius. Design to the specific turning radius and additional checking through 3D modeling	3D modeling software and measuring equipment

Measurements and Confirmation

Targets will primarily be verified through rover system design, modeling, prototyping, and road testing. With many of the targets being geometric requirements (e.g. height, length, width) the use of 3D CAD software will be useful in ensuring targets are met considering the geometry of the rover. For example, clearance of moving parts within the device will be confirmed using 3D modeling before manufacturing which ultimately saves time and money.

Additionally, many of the targets specify desired components; these targets will be satisfied by designing and accommodating components which fulfil system functions which the target quantifies. Computations will also be made during validation, for example, rider related component height of 14 inches. The compression of suspension and other deflection must be considered as well as the weight of the riders. Mission-critical targets such as rider related component height will be heavily considered in design, computations, and testing in order to satisfy requirements and fulfil the aspired targets.

1.5 Concept Generation

Generation Methods

The Morphological Chart

The team found that the morphological chart was the most effective method of generating concepts for this project since most of the design is guided and regulated by the competition guidebook. This does not necessarily mean that the components cannot be innovative; however, certain systems are expected or required to be present. The following table represents the morphological chart; a concept or multiples are selected from each column respectively. Table 1.5.2 displays an example of a generated concept from the morphological chart. A rover utilizing coil springs and damper suspension, mechanical steering, chain and gearbox driven drivetrain, and foam core, treaded wheels is exemplified in this table.

Table 8.5.1
Morphological Chart

Suspension	**Steering**	**Drivetrain**	**Wheels**

• Linkage • Coil Spring/ Dampener • Leaf Springs • Independent • Rigid • Wheel Integrated	• Hydraulic • Rear • Front • Mechanica l • Cable	• Chain Drive • Differential • CVT • Shaft Driven • Linkage • Gearbox • Single or Double Input • Tracks	• Integrated Spring/ Dampener • Pneumatic • Treaded • Foam Core

Table 9.5.2
Generated Concept Example

Suspension	**Steering**	**Drivetrain**	**Wheels**
• Linkage • Coil Spring /Dampener • Leaf Springs • Independent • Rigid • Wheel Integrated	• Hydraulic • Rear • Front • Mechanical • Cable	• Chain Drive • Differential • CVT • Shaft Driven • Linkage • Gearbox • Single or Double Input • Tracks	• Integrated Spring /dampener • Pneumatic • Treaded • Foam Core

Brainstorming

In addition to the morphological chart, many concepts were also gathered during team brainstorming sessions. The team would bounce ideas off one another and the concepts were built upon them. During this process any idea that was proposed was written down and collected regardless of the practicality of the idea. The sessions also featured ideas around the SCAMPER (Substitute. Combine. Adapt. Modify. Put to other use. Eliminate. Rearrange) technique.

Random Input Technique

The random input technique was used in conjunction with brainstorming to generate some additional ideas. Some of the concepts from brainstorming spurred related concepts with keywords in their description. AN example of this would be the ski wheel concept that was generated once the idea of a sled was introduced.

Biomimicry

The team also used the biomimicry technique, which is a method of looking to nature and natural phenomenon to generate concept ideas. When deriving concepts for the rover wheels the team looked at the pangolin which can roll itself into a ball. The team also looked toward the pelican to generate concepts for the sample collection tasks. The pelican was used because of its ability to scoop water and fish into its bill quickly and efficiently which gave way to the idea of the Cap n' Go listed in Table E1 of the generated concepts list.

Medium Fidelity Concepts

Ski-Prone Pilot

The Ski-Prone Pilot design was formed from brainstorming and the use of the morphological chart. The front wheels of the rover are replaced with a pair of skis resembling that of a snowmobile. The rider that steers lies prone, held in place by a harness secured to the bottom of the second riders' seat.

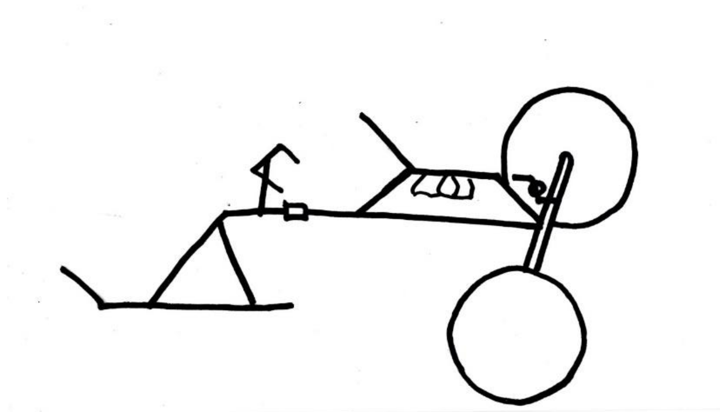


Figure 7.5.1 Ski-Prone Pilot Concept Rendering

Built-In Tire Suspension

The Built-In tire suspension design came as a result of the morphological chart. The tire has a segmented rim with independent spoke suspension. The suspension of the wheel is jointed to allow for compression with a spring dampener in between the linkages in order to absorb some of the energy from bumps and shocks.

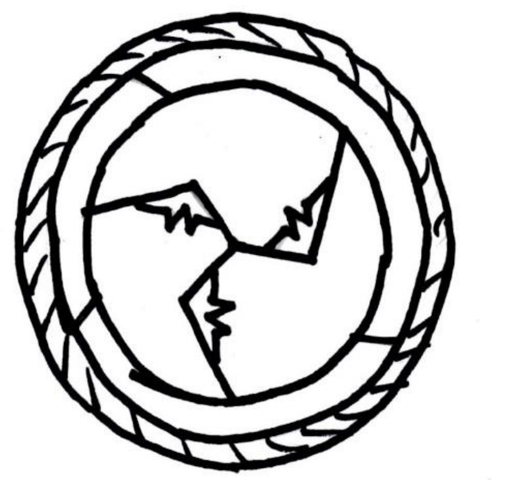


Figure 8.5.2 Built-In Tire Suspension Concept Rendering

Sideways Trike

The Sideways Trike design was derived from the morphological chart and brainstorming. This design has the riders back-to-back and allows for single or dual input. The two wheels on one side of rover provides stability while the single wheel on the opposite side allows for maneuverability with a significant weight reduction.

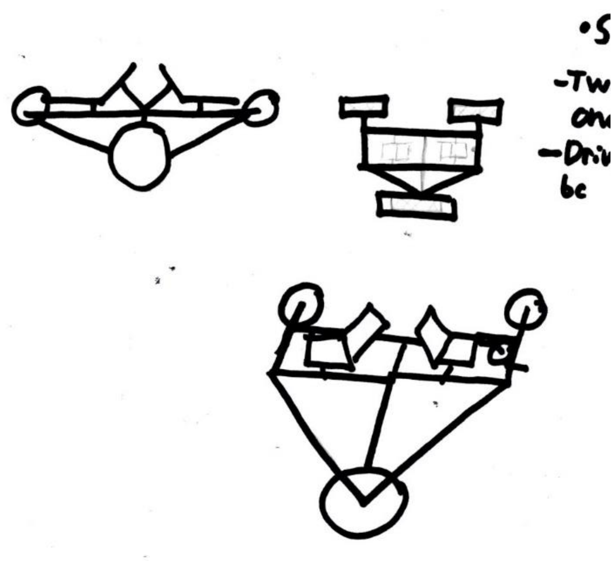


Figure 9.5.3 Sideways Trike Concept Rendering

Prone Pilot Tricycle

The Prone Pilot Tricycle design is derived from brainstorming, by adapting the tricycle known from many people's childhood, to allow for one rider to be lying prone and secured in place with a harness while the second rider provides power to the rear axle.

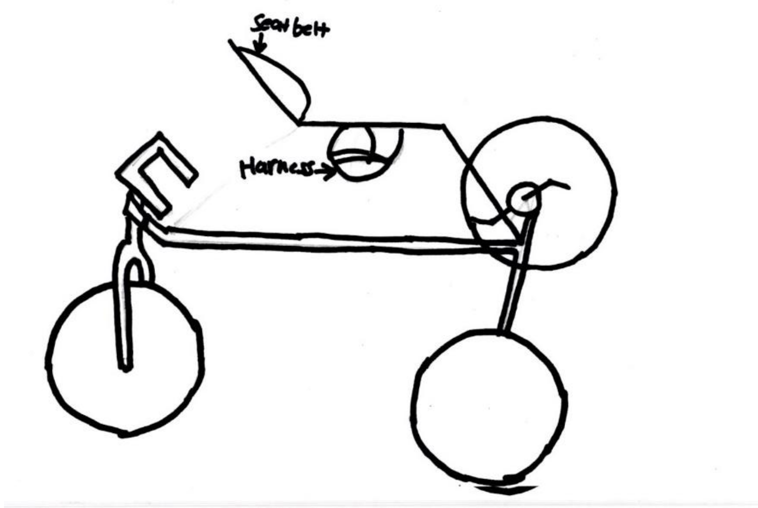


Figure 10.5.4 Prone Pilot Tricycle Concept Rendering

Diamond Rover

The Diamond Rover design is a unique four-wheeled rover layout derived from the use of the morphological chart. The Diamond Rover uses a rigid bi-wheel fork to controls the front wheel for steering. The rear wheel provides both support and act as a method for even weight distribution for traversing on softer terrain. Adaptable for dual or single driver input.

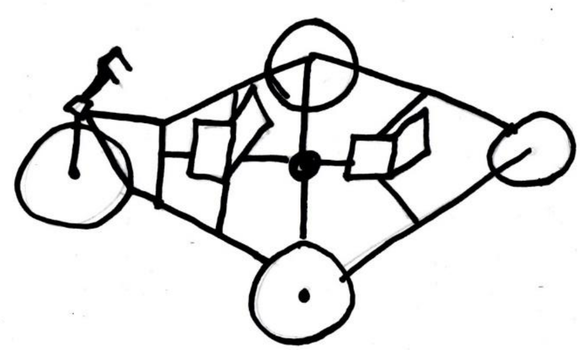


Figure 11.5.5 Diamond Rover Concept Rendering

High Fidelity Concepts

Rigid Bi-Wheel Fork

The Rigid Bi-Wheel Fork design accepts an input from a four-bar crank-rocker steering system. The Rigid fork will not contain any suspension elements. The bearing block is fixed to the chassis of the rover, as the fork is intended for use with larger wheels to compensate for the lack of a suspension system.

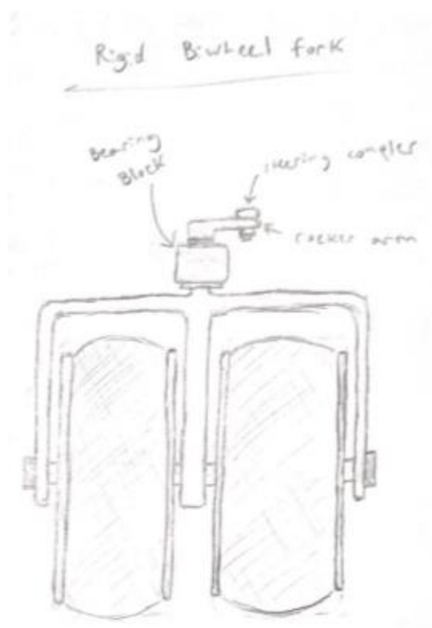


Figure 12.5.6 Rigid Bi-Wheel Fork Concept Rendering

Ski-Fork

The Ski-Fork design utilizes two skis along each side of the central wheel. Only one ski is illustrated in Figure 1.5.7 below. The skis are used to stabilize the vehicle and assist with the vehicles ability to steer and orient itself.

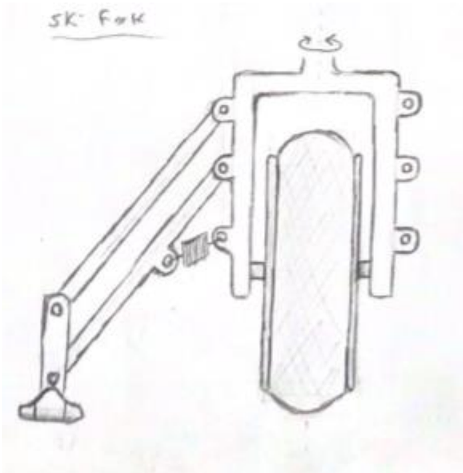


Figure 13.5.7 Ski-Fork Concept Rendering

Single Input Driver Layout

The Single Input Driver Layout design has one of the rover drivers providing propulsion through the pedals. The other driver is slightly elevated in the rear of the rover steering. This system allows for a simpler drivetrain but would see a smaller magnitude or propulsion energy generated.

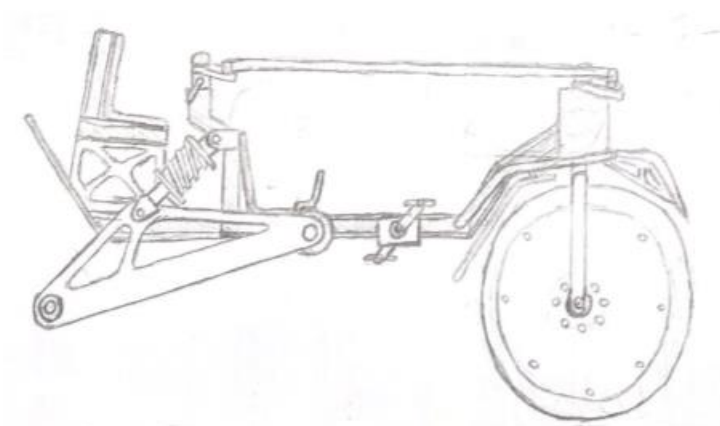


Figure 14.5.8 Single Input Driver Layout Concept Rendering

Solid-Axle Double-Input Drivetrain

The Solid-Axle Double-Input Drivetrain design utilizes chain drives for driver input. There will be no torque manipulation, shifting of gears, from sprocket to sprocket to avoid the chance of chain derailment. The suspended portions of the drivetrain will not include the chain-driven parts in order to prevent the potential failure of the system. The final sprocket will drive a 90-degree gearbox that drives a universal joint. The U-joint will allows for rear suspension of the solid axle. The U-joint will be coupled with another shaft that feeds a single-input, double-output, locked gearbox. The gearbox then ultimately providing torque to the wheels. Struts and control arms will be jointed to the axle supporting suspension travel.

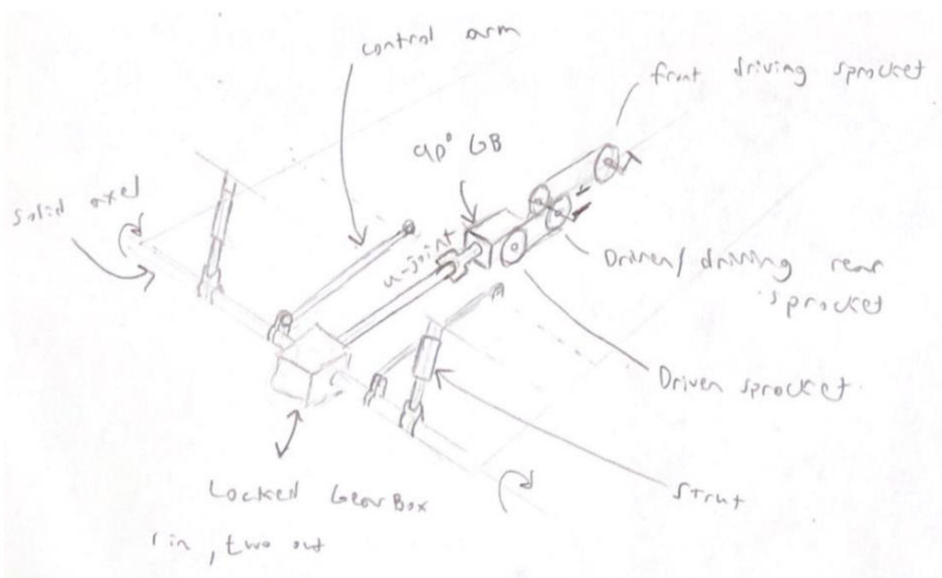


Figure 15.5.9 Solid-Axle Double-Input Drivetrain Concept Rendering

Foam Core Wheel

The Foam Core Wheel design features a metal hub, containing bearings, a fiberglass shell, rubber treads, and an injected foam core for structural support. The wheel is not pneumatic, and materials will be designed to withstand various impacts and weather conditions. The illustration shown in Figure 1.5.10 shows the top half of a cross-section of the proposed wheel.

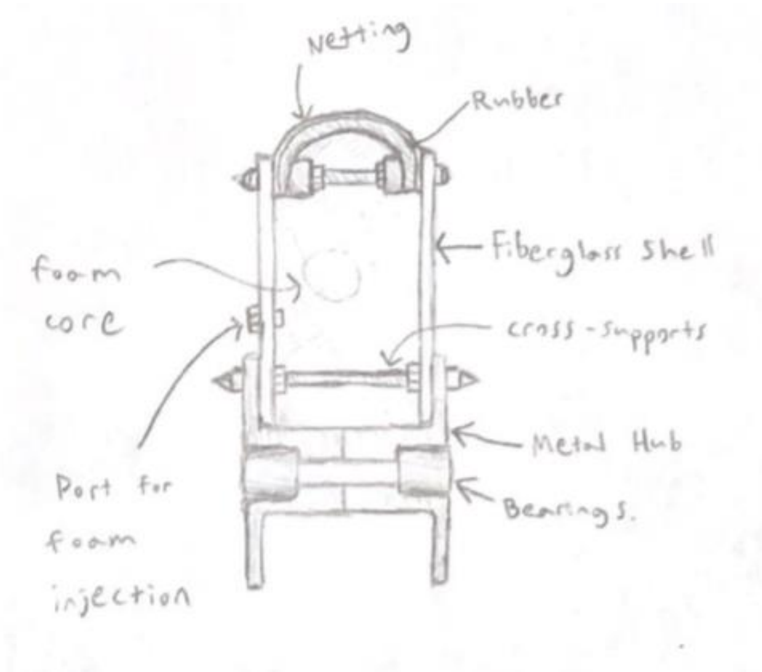


Figure 16.5.10 Foam Core Wheel Concept Rendering

Independent Suspension Fork

The Independent Suspension Fork design has a front suspension fork which accepts input from a four-bar crank-rocker steering system. The fork allows for a small turning radius which is required from the guidebook, as well as having vibration and impact dampening abilities. The travel height of the rover will be designed and optimized to accommodate for the competition minimum clearance height requirements.

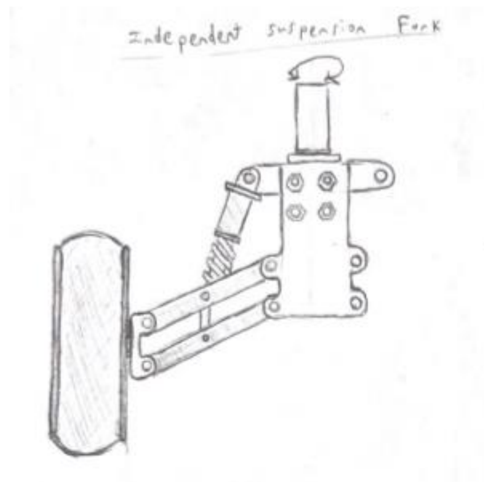


Figure 17.5.11 Independent Suspension Fork Concept Rendering

<u>Linkage Drivetrain</u>

The linkage drivetrain design avoids the usage of chain drives, shafts, couplers, and other components that have historically failed during the competition. Figure 1.5.12 shows a 3D CAD model of the proposed concept. The cranks accept pedaling power from both riders and are shown in red. The two cranks are coupled on each side to form a four-bar double crank mechanism. The rear crank has a joint which slide into a slot in the rocking arm and is colored green. This rocking arm is then joined to another rocking arm which transmits torque to a ratcheting hub; the hub is colored teal. Friction and structural integrity are a large concern for this mechanism design. There will be dynamic and structural analysis conducted to mitigate possible risks.

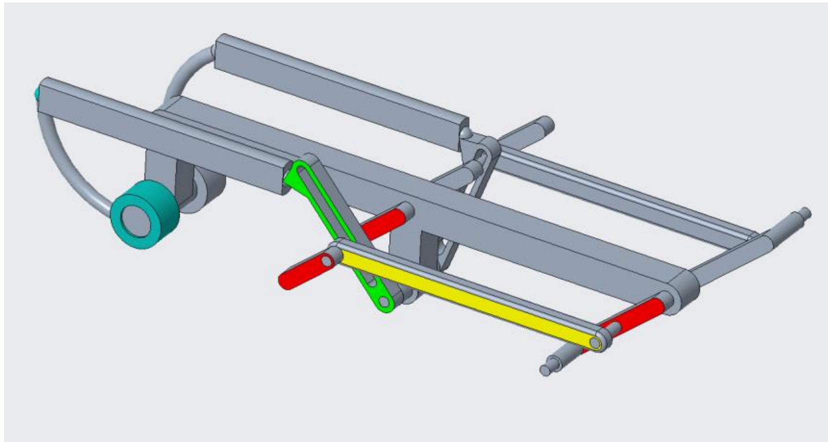


Figure 18.5.12 Linkage Drivetrain Concept Rendering

<u>Custom Variable Viewfinder</u>

The custom variable viewfinder design is a simple design allowing for quick changing of the filters in front of the camera lens. The mechanism will attach itself with some sort of adhesive to the camera and will contain 3 filters, one red, one blue, and one yellow. These filters will be able to pivot around the point that is attached to the camera. Similar to an eye exam machine with the differing lens swapping in front of the viewfinder.

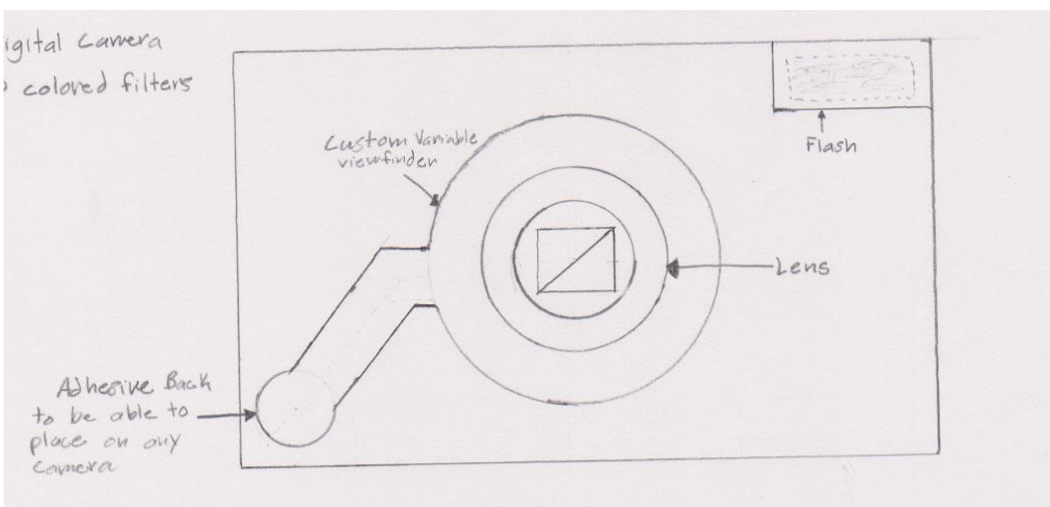


Figure 19.5.13 Custom Variable Viewfinder Concept Rendering

Deployable Solar Cell

The deployable Solar Cell design is a relatively simple circuit housed in a case with a transparent bottom for competition purposes. The majority of the housing units' surface will be taken up by a phototactic cell maximizing the amount of potential power generation for the form factor. The design will also be compact so that the rover drivers are able to store the instrument on their person. An illustration of the proposed concept is depicted in Figure 1.5.14

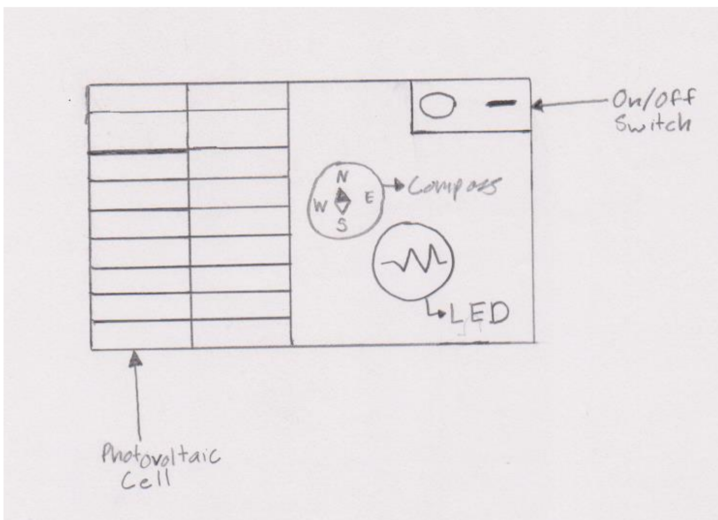


Figure 20.5.14 Deployable Solar Cell Concept Rendering

1.6 Concept Selection

Binary Comparison

The mission critical customer requirements set forth by the NASA 2020 Human Exploration Rover Guidebook and those derived by the team were analyzed using a binary comparison table shown in Table 1.6.1. The table produces a hierarchy of importance amongst the customer requirements relative to one another. This hierarchy which provides a weight factor, is later used in numerically analyzing the merits of the generated concepts.

Table 10.6.1
Binary Comparison Table

	1	2	3	4	5	6	7	8	9	10	Total
1.Machinability	-	0	1	0	0	0	0	0	1	0	2
2.Innovative	1	-	1	0	0	0	0	0	1	0	3
3.Cost Effective	0	0	-	0	0	0	0	0	1	0	1
4.Simplicity	1	1	1	-	0	0	1	1	1	0	6
5.Reliability	1	1	1	1	-	1	1	1	1	1	9
6.Assembly	1	1	1	1	0	-	1	0	1	0	6
7.Impact Dampening	1	1	1	0	0	0	-	0	1	0	4
8.Control	1	1	1	0	0	1	1	-	1	1	7
9.Required Input	0	0	0	0	0	0	0	0	-	0	0
10.safety	1	1	1	1	0	1	1	0	1	-	7
Total	7	6	8	3	0	3	5	2	9	2	

House of Quality

The House of Quality (HoQ) determines how certain engineering characteristics of the rover system design satisfy the customer needs. The relative weights and the ranked order of the engineering characteristics come as a result of the HoQ which assists in comparing concepts to one another to ultimately reveal which concepts best satisfy the stated customer needs.

Table 11.6.2
House of Quality

		Engineering Characteristics						
Improvement direction		↑	↑	↓	↑	↑	↓	↑
Units		# of extremities	in	in*lbf	in*lbf, lbf	in	in	
Customer Requirements	Importance weight factor	Driver Mobility	Rider size accommodation	Driver Input	Rover Output	Rider position height	Turning Radius	Rover Stability
Control	7	8	4	8	8	4	8	8
Reliability	9	4	0	4	4	2	4	8
Simplicity	6	1	0	4	4	0	1	4
Impact Dampening	4	0	0	2	8	0	0	8
Assembly	6	0	1	8	4	1	2	2
Innovative	3	2	0	8	4	0	1	4
Cost effective	1	2	0	8	8	0	0	4
Safety	7	8	8	4	4	8	4	8

Machinability	2	0	2	8	4	0	0	2
Raw score (1253)		162	94	248	228	108	141	272
Relative Weight (%)		12.9	7.5	19.8	18.2	8.6	11.3	21.7
Rank Order		4	7	2	3	6	5	1

Pugh Charts

Pugh chart comparisons were used to analyze concepts of similar systems. The four systems that were analyzed are the front suspension, wheel design, driver layout, and drivetrain. Multiple iterations were conducted on each of the various systems until a concept was proven to better satisfy customer needs than the others. For example, if a concept was proven to be the best during subsequent analyses it would be deemed the best concept to satisfy the customer needs. This analysis was performed for all four systems to be used further in determining which concepts will move to greater stages of development.

The Pugh Chart shown in Table 1.6.3 below compares the concepts for the front suspension to the datum concept of the Rockshox Recon Suspension Fork. The concepts that are determined to be worse than the datum is denoted by minuses (-), concepts determined to be better than the datum are denoted by pluses (+), and those that are equivalent to the datum are denoted by an S. The Independent Suspension Fork has the fewest minuses with 1 and the greatest number of pluses with 3, which sets it up to be the datum chosen in the subsequent Pugh chart regarding the front suspension.

Table 12.6.3

Front Suspension Pugh I

Front Suspension					
	Concepts				
Selection Criteria	Datum	Independent Suspension fork	Ski Fork	Rigid Bi-Wheel Fork	Independent Linkage Fork
Rover Stability	Rockshox recon suspension fork 	+	+	+	+
Driver Input		-	-	-	-
Rover Output		+	-	-	-
Driver Mobility		S	S	-	+
Turning Radius		+	S	S	-
Rider position height		S	S	S	S
Rider Size Accommodation		S	S	S	S
# pluses		3	1	1	2
# minuses		1	2	3	3

The Pugh Chart in Table 1.6.4 is the second chart for the front suspension. The concepts are compared to the datum established in the Table 1.6.3. The Independent Linkage Fork has the greatest number of pluses with 1 and is tied for the least number of minuses with 3.

Table 13.6.4
Front Suspension Pugh II

Front Suspension				
	Concepts			
Selection Criteria	Datum	Ski Fork	Rigid Bi-Wheel Fork	Independent Linkage Fork
Rover Stability	Independent Suspension fork	-	-	+
Driver Input		-	-	-
Rover Output		-	-	-
Driver Mobility		S	-	S
Turning Radius		S	S	-
Rider position height		S	S	S
Rider Size Accommodation		S	S	S
# pluses		0	0	1
# minuses		3	4	3

The Pugh Chart in Table 1.6.5 below compares the concepts for the Wheel Designs to the datum concept the Tubed, Schrader valve, Pneumatic bicycle wheel. The concept chosen to be the new datum for the next Pugh chart is the Foam core wheel as it has the fewest number of minuses with 0.

Table 14.6.5
Wheel Design Pugh I

Wheels					
	Concepts				
Selection Criteria	Datum	Foam Core Wheel	Integrated Suspension Wheel	Rigid Wheel	Full Metal Wheel
Rover Stability	Tubed, Schrader valve, Pneumatic bicycle wheel 	S	-	S	S
Driver Input		S	-	S	S
Rover Output		S	+	-	-
Driver Mobility		S	S	S	S
Turning Radius		S	S	S	S
Rider position height		S	S	S	S
Rider Size Accommodation		S	S	S	S
# of pluses		0	1	0	0
# of minus		0	2	1	1

The datum for the Pugh Chart in Table 1.6.6 below was determined from the previous chart and is compared to the remaining concepts. The Pugh Chart reveals that the Rigid Wheel should be chosen as the new datum and was evaluated using the same methods as the previous Pugh Chart.

Table 15.6.6
Wheel Design Pugh II

Wheels				
	Concepts			
Selection Criteria	Datum	Integrated Suspension Wheel	Rigid Wheel	Full Metal Wheel
Rover Stability	Foam Core Wheel	-	S	S
Driver Input		-	-	-
Rover Output		-	-	-
Driver Mobility		S	S	S
Turning Radius		S	S	S
Rider position height		S	S	S
Rider Size Accommodation		S	S	S
# of pluses		0	0	0
# of minus		3	2	2

The wheel concept chosen in the Pugh Chart from Table 1.6.6 is used as the new datum for the Pugh chart in Table 1.6.7. Based off the Pugh chart in Table 1.6.7 below the Foam Core Wheel has the fewest minuses with 0 and the greatest number of pluses with 2.

Table 16.6.7

Wheels Pugh III

Wheels				
	Concepts			
Selection Criteria	Datum	Integrated Suspension Wheel	Foam Core Wheel	Full Metal Wheel
Rover Stability	Rigid Wheel	-	+	-
Driver Input		-	S	-
Rover Output		-	+	-
Driver Mobility		S	S	S
Turning Radius		S	S	S
Rider position height		S	S	S
Rider Size Accommodation		S	S	S
# of pluses		0	2	0
# of minus		3	0	3

The Pugh Chart in Table 1.6.8 below compares the concepts for the Driver Layout to the datum concept the Front-to-Back, Tandem Style. Though the Back to Back concept has the fewest minuses with 0 and has the greatest number of pluses with 2, the Side by Side concept is used as the datum for the next Pugh chart.

Table 17.6.8

Driver Layout Pugh I

Driver Layout					
	Concepts				
Selection Criteria	Datum	Variable height, front to back	Side by side	Back to Back	Rear Steering, One Input
Rover Stability	Front to Back, Tandem Style 	S	S	S	S
Driver Input		S	-	S	+
Rover Output		S	S	S	-
Driver Mobility		S	S	S	S
Turning Radius		+	+	+	S
Rider position height		S	+	+	S
Rider Size Accommodation		S	S	S	S
# of pluses		1	2	2	1
# of minus		0	1	0	2

The chart in Table 1.6.9 is the second Pugh Chart for driver layout. The datum chosen in the previous Pugh Chart is compared to the remaining concepts. The concept with the greatest number of pluses is the Variable height, front to back with 2.

Table 18.6.9

Driver Layout Pugh II

Driver Layout				
	Concepts			
Selection Criteria	Datum	Variable height, front to back	Back to Back	Rear Steering, One Input
Rover Stability	Side by side	-	S	-
Driver Input		+	+	-
Rover Output		+	S	-
Driver Mobility		S	S	+
Turning Radius		-	S	S
Rider position height		S	S	S
Rider Size Accommodation		S	S	S
# of pluses		2	1	1
# of minus		2	0	3

The Pugh Chart in Table 1.6.10 is for the Drivetrain concepts. The datum that was chosen is the Rigid Tandem, chain driven drivetrain and it is compared to the remaining concepts. The Linkage Drivetrain is the chosen to be the new datum for the next chart with the fewest number of minuses.

Table 19.6.10
Drivetrain Pugh I

Drivetrain					
	Concepts				
Selection Criteria	Datum	Linkage Drivetrain	Solid-Axle Double-Input Drivetrain	Chain Ring Legs with Pedal Driven Gearbox System	Directly Driven Shaft (Pedal Boat)
Rover Stability	Rigid Tandem, chain driven drivetrain	+	+	+	-
Driver Input		S	S	S	-
Rover Output		+	+	+	-
Driver Mobility		S	S	S	-
Turning Radius		S	S	S	S
Rider position height		S	S	S	S
Rider Size Accommodation		S	S	S	S
# of pluses		0	0	0	0
# of minus		2	2	2	4

<u>Analytical Hierarchy Process (AHP)</u>

An Analytical Hierarchy Process was conducted to compare concepts of similar systems in a non-binary manor to be used in determining which concepts best satisfy our customer needs.

The concepts were compared to one another and their relationship is then normalized to numerically determine which concept best satisfies our customer needs.

Table 20.6.11
Front Suspension AHP

Front Suspension				
	Independent Suspension Fork	Ski Fork	Rigid Bi-Wheel Fork	Independent Linkage Fork
Independent Suspension Fork	1	3	2	2
Ski Fork	.33	1	.5	.33
Rigid Bi-Wheel Fork	.5	2	1	.5
Independent Linkage Suspension	.5	3	2	1
Sum	2.33	9	5.5	3.83

Table 21.6.12
Front Suspension Normalization

Normalized Front Suspension					
	Independent Suspension Fork	Ski Fork	Rigid Bi-Wheel Fork	Independent Linkage Fork	Weight
Independent Suspension Fork	.43	.33	.36	.52	.41
Ski Fork	.14	.11	.09	.09	.11
Rigid Bi-Wheel Fork	.21	.22	.18	.13	.19

Independent Linkage Suspension	.21	.33	.36	.26	.29
Sum	1	1	1	1	1

The Front Suspension Normalization table in Table 1.6.12 revealed that the independent suspension fork would satisfy our customer needs best as it yields the greatest normalization value. This analysis was conducted for all four of the rover systems.

Table 22.6.13
Front Suspension Consistency Check

Front Suspension Consistency Check			
	Criteria Weights {W}	Weighted Sum Vector {Ws} = [C]{W}	Consistency Vector Cons = {Ws}./{W}
Independent Suspension Fork	0.41	1.990	4.854
Ski Fork	0.11	0.436	3.964
Rigid Bi-Wheel Fork	0.19	0.760	4.000
Independent Linkage Suspension	0.29	1.205	4.155

Table 23.6.14
Front Suspension Consistency Comparison

Front Suspension Consistent Comparison			
Average Consistency	n	Consistency Index CI	Consistency Ratio CR
4.243	4	0.0092	0.081

A consistency check was performed on the front suspension design to check for any biases amongst the different generated concepts. The weight criteria is found for each concept within the system, and to determine this criteria a series of calculations were performed to determine the consistency vector. The consistency vector shows how much bias was involved in the selection process of each of the concepts. From this the average consistency is found and can be used to find the consistency index which is used to find the consistency ratio (CR). The CR was found to be 0.081, if the CR is less than 0.10 it means that the concepts were evaluated in a consistent manor in the AHP comparisons. The lower the value of CR the more consistent and least amount of bias was involved in the selection process. This process was conducted for all four of the rover systems.

Table 24.6.15
Wheel Design AHP

Wheel Design AHP				
	Foam Core Wheel	Integrated Suspension Wheel	Rigid Wheel	Full Metal Wheel
Foam Core Wheel	1	4	2	3
Integrated Suspension Wheel	.25	1	.33	.5
Rigid Wheel	.5	3	1	2

Full Metal Wheel	.33	2	.5	1
Sum	2.08	10	3.83	6.5

Table 25.6.16
Normalized Wheel Design AHP

Normalized Wheel Design AHP					
	Foam Core Wheel	Integrated Suspension Wheel	Rigid Wheel	Full Metal Wheel	Weight
Foam Core Wheel	.48	.4	.52	.46	.47
Integrated Suspension Wheel	.12	.1	.09	0.08	.10
Rigid Wheel	.24	.3	.26	.31	.28
Full Metal Wheel	.16	.2	.13	.15	.16
Sum	1.00	1.00	1.00	1.00	1

The Normalized Wheel Design AHP in Table 1.6.16 shows that the Foam Core Wheel design would best satisfy our customer needs as it has the greatest normalized weight.

Table 26.6.17

Wheel Design Consistency Check

Wheel Design Consistency Check			
	Criteria Weights {W}	Weighted Sum Vector {Ws} = [C]{W}	Consistency Vector Cons = {Ws}./{W}
Foam Core Wheel	0.47	1.910	4.064
Integrated Suspension Wheel	0.10	0.390	3.900
Rigid Wheel	0.28	1.135	4.054
Full Metal Wheel	0.16	0.655	4.094

Table 27.6.18

Wheel Design Consistency Comparison

Wheel Design Consistency Comparison			
Average Consistency	n	Consistency Index CI	Consistency Ratio CR
4.028	4	0.0092	0.010

The consistency ratio was 0.010. This proves that the decision making on the concepts were consistent and unbiased as the consistency ratio is less than 0.1.

Table 28.6.19

Driver Layout AHP

Driver Layout AHP				
	Variable height, front to back	Side by side	Back to Back	Rear Steering, One Input
Variable height, front to back	1	2	2	4

Side by side	.5	1	.5	3
Back to Back	.5	2	1	3
Rear Steering, One Input	.25	.33	.33	1
Sum	2.25	5.33	3.83	11

Table 29.6.20

Normalized Driver Layout AHP

Normalized Driver Layout AHP					
	Variable height, front to back	Side by side	Back to Back	Rear Steering, One Input	Weight
Variable height, front to back	.44	.38	.52	.36	.43
Side by side	.22	.19	.13	.27	.20
Back to Back	.22	.38	.26	.27	.28
Rear Steering, One Input	.11	.06	.09	.09	.09
Sum	1	1	1	1	1

The Normalized Driver Layout AHP in Table 1.6.20 shows that the Variable Height, Front to Back concept would best satisfy our customer needs as it has the greatest normalized weight.

Table 30.6.21
Driver Layout Consistency Check

Driver Layout Consistency Check			
	Criteria Weights {W}	Weighted Sum Vector {Ws} = [C]{W}	Consistency Vector Cons = {Ws}./{W}
Variable height, front to back	0.43	1.750	4.070
Side by Side	0.20	0.825	4.125
Back to Back	0.28	1.165	4.161
Rear Steering, One input	0.09	0.356	3.956

Table 31.6.22
Driver Layout Consistency Comparison

Driver Layout Consistent Comparison			
Average Consistency	n	Consistency Index CI	Consistency Ratio CR
4.078	4	0.026	0.029

The consistency ratio was also found for the driver layout AHP. The consistency ratio was found to be 0.029. Thus, the AHP is consistent and unbiased.

Table 32.6.23
Drivetrain AHP

Drivetrain				
	Linkage Drivetrain	Solid-Axle Double-Input Drivetrain	Chain Ring Legs with Pedal Driven Gearbox System	Directly Driven Shaft (Pedal Boat)

Linkage Drivetrain	1	.33	.25	2
Solid-Axle Double-Input Drivetrain	3	1	.5	3
Chain Ring Legs with Pedal Driven Gearbox System	3	2	1	4
Directly Driven Shaft (Pedal Boat)	.5	.33	.25	1
Sum	7.5	3.66	2	10

Table 33.6.24
Normalized Drivetrain AHP

Normalized Drivetrain					
	Linkage Drivetrain	Solid-Axle Double-Input Drivetrain	Chain Ring Legs with Pedal Driven Gearbox System	Directly Driven Shaft (Pedal Boat)	Weight
Linkage Drivetrain	.13	.09	.125	.2	.14
Solid-Axle Double-Input Drivetrain	.4	.27	.25	.3	.31
Chain Ring Legs with Pedal Driven Gearbox System	.4	.55	.5	.4	.46
Directly Driven Shaft (Pedal Boat)	.07	.09	.125	.1	.10

Sum	1	1	1	1	1

The Normalized Drivetrain table shows that the Chain Ring Legs with Pedal Driven Gearbox System should best satisfy our customer needs as it has the greatest normalized weight.

Table 34.6.25
Drivetrain Consistency Check

Drivetrain Consistency Check			
	Criteria Weights {W}	Weighted Sum Vector {Ws} = [C]{W}	Consistency Vector Cons = {Ws}./{W}
Linkage Drivetrain	0.14	0.557	3.979
Solid-Axle Double-Input Drivetrain	0.31	1.260	4.065
Chain Ring Legs with Pedal Driven Gearbox System	0.46	1.900	4.130
Directly Driven Shaft (Pedal Boat)	0.10	0.387	3.870

Table 35.6.26
Drivetrain Consistency Comparison

Drivetrain Consistent Comparison			
Average Consistency	n	Consistency Index CI	Consistency Ratio CR
4.011	4	0.004	0.004

Finally, the consistency ratio was found for the drivetrain AHP. The consistency ratio found was 0.004. This number is considerably smaller than the required CR value of 0.1. This proves that drivetrain concepts comparisons on the AHP were unbiased.

Selection

The concept selection methods performed previously were used in the actual selection as suggestions not necessarily used at strict guidelines; there are several criteria that were considered in the final selection that were not included in the analysis such as viability considering the team's capabilities. Every selected concept won its respective Pugh and AHP analysis except for the drivetrain selection. The linkage drivetrain was selected due to its perceived viability and the opportunity to produce something very innovative.

Table 36.6.27
Selected System and Concept

Selected Concepts	
System	***Concept***
Front suspension	Independent suspension Fork
Wheels	Foam Core Wheels
Driver Layout	Variable Height Front to Back
Drivetrain	Linkage Drivetrain

The following table presents the selected concepts, features, and reasoning for selecting.

Table 37.6.28
Selected Concepts

Independent Suspension Fork: ● Deemed the greatest front suspension concept by Pugh Chart and Analytical Hierarchy Process ● Concept is viable and effective in dampening impacts and guiding rover
Foam Core Wheels ● Deemed the best wheel concept by Pugh chart and Analytical Hierarchy Process. ● Offers lightweight, low inertia, low cost wheels.
Variable Height Front to Back ● Deemed the greatest driver layout concept by Pugh Chart and Analytical Hierarchy Process ● Allows two inputs while accommodating size restrictions
Linkage Drivetrain: ● Viable, Unique, and innovative system. ● Did not win selection method analysis, however, the linkage drivetrain will be an impressive system if executed properly

If the selected concepts are proven to be inadequate or not viable the concepts considered for R&D will be implemented instead. Development of these concepts will be performed in parallel with the selected concepts until a proof of viability is produced.

Table 38.6.29
Selected Concepts Considered for R&D

Concepts Considered for R&D	
System	***Concept***
Front suspension	Rigid Bi-Wheel Fork
Wheels	Rigid Wheels
Driver Layout	Back to Back
Drivetrain	Solid Axle, double input

1.8 Spring Project Plan

Figure 1.8.1 below displays the critical path methodology in which work will be conducted in the near future.

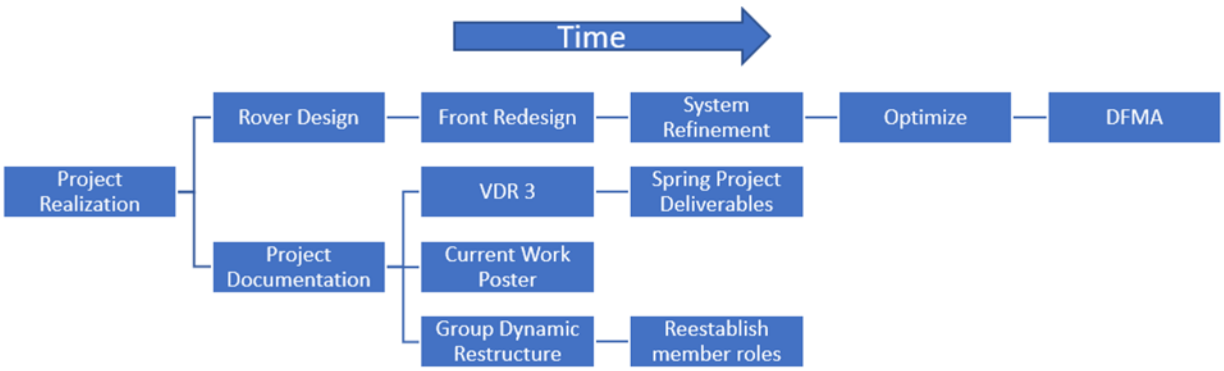


Figure 21.8.1 Project Critical Path Methodology

- Academic Calendar Milestones
  - a. Project Milestone needed to be completed by then
    - i. Important step to completing Project Milestone
  - b. Project Milestones
    - i. Spring Deliverables

I. First day of Spring Semester (Jan 6, 2020)

- a. Detailed Design
  - i. Chassis Design
    1. Seat Selection
    2. Attachment Points
    3. FEA
    4. Material selection
       - a. Cost analysis
       - b. Weight optimization
  - ii. Wheel Design
    1. Hub Selection
    2. Attachment points
    3. FEA
    4. Material selection
       - a. Cost analysis
       - b. Weight optimization
  - iii. Drivetrain Design
    1. Pedal Location Selection

2. Attachment Points
3. Constant Output design
4. FEA
5. Material selection
    a. Cost analysis
    b. Stress analysis
    c. Weight optimization

iv. Compacting Design solution
1. Alteration of detailed design to compact into a 5 x 5 x 5 ft volume
2. Attachment points

v. Task completion Designs
1. Designs for completing tasks on Creo/SolidWorks
2. 3-D print task design instrumentation
3. Manufacture task designs
4. Test and tweak designs
5. Weight optimization

II. Registration For competition closes (Jan 16, 2020)
- a. Team registration must be complete.

III. Competition release forms due
- a. Student data feedback form
- b. Media Release Forms
- c. Final list of team members.

IV. Team Photos March (13, 2020)
- a. Photo Included all team members and clear photo of rover

i. Chassis Fabrication
1. Size requirements
2. Weight requirement
3. stability

ii. Wheel Fabrication
1. Proper Documentation
    a. Student design and fabrication
    b. Completion report completed

iii. Drivetrain Fabrication
1. Proper Documentation
    a. Student design and fabrication
    b. Completion report completed

iv. Task Fabrication
1. Task equipment testing

V. Spring Break (March 16-20, 2020)

  a. Rover Assembly
  b. Additional material selection
     i. Approved Helmets
     ii. Approved clothing
  c. Testing critical targets and metrics
     i. Does it roll
     ii. Turning radius
        1. 15 foot turning radius
     iii. Weight
        1. < 200 lbs. unload
        2. < 600 lbs. loaded
     iv. Size
        1. Unfolded less than 5ft in width
        2. Compacted to fit within 5ft^3 box
     v. Stability
        1. Center of mass calculation
     vi. Clearance
        1. 14-inch rider clearance
     vii. Braking
        1. Appropriate braking distance.

VI. Travel to competition (April 15, 2020)

  a. Complete Rover shipped/arrived at competition location
  b. Travel for team to competition
  c. Lodging for the weekend

VII. Competition Date in Huntsville, Al (April 16-18, 2020)

  a. April 16, 2020, 12:00-4:00 pm Team Check in

VIII. Engineering Design Day (*April 18, 2019*)

  a. Presentation Prepared
     i. Design
     ii. Fabrication
     iii. Competition

IX. Finals (April 27, 2020)

X. Graduation (May 2, 2020)
@ 9:00 am Donald L. Tucker Civic Center

Chapter Two: EML 4552C

2.1 Spring Plan

Project Plan.

Build Plan.

Appendices

Appendix A: Code of Conduct

Mission Statement

Our team is dedicated to upholding professional practices, proper engineering design methods, and cooperation amongst ourselves and project stakeholders. Our goal is to exceed project expectations, displaying adequate performance in competition, by executing a methodical design process and producing an innovative product.

Team Member Roles

All team members participated in the designation of the team roles. The desire of the team members' role in the project, relevance and applicability to the project, and the workload associated with each respective position was considered during the designation of roles.

<u>Design Engineer: Phillip Dimacali</u>

- Produce mechanical 3D modeling and simulations
- Lead drivetrain, wheel, and suspension design

<u>Mechanical Engineer: Jessica Meeker</u>

- Optimize mechanical systems for cost, structural, and functional efficiency
- Verify designs for manufacturing

<u>Manufacturing Engineer: Lazaro Rodriguez</u>

- Responsible for purchasing and installing equipment
- Collaborate with mechanical engineer on product and cost efficiency
- Improving production by collaborating with design engineer
- Planning and organizing maintenance on vehicle

Project Engineer: Tavares Butler

- Manage and review project documents
- Liaison between project team members and immediate stakeholders

Quality Engineer: Jerald Yee

- Ensure team is ahead of project deadlines
- Provide quality assurance of project productions including documentation, prototypes, final products

Communication

The main form of communication for our team will be through group text, and file sharing will be done through Google Docs and Microsoft Outlook. All team members will have access to the shared Google Doc and Outlook files. The team will use our school email to contact our sponsor and advisor to set up meetings and ask questions. Team members will be responsible for checking messages and emails regularly and responding within 24 hours from the initial contact. Each member is responsible for being appropriate and respectful throughout all communication, both with each other and with our sponsor and advisor.

Dress Code

Team meetings:

For general scheduled team meetings, casual attire will be acceptable.

Advisor/Sponsor Meetings:

For meetings with our advisor or sponsor, our team will be in business casual attire. This includes dress shirts, polo shirts, blouses, long pants, professional skirts, and closed toed shoes.

Presentations:

For presentations, the entire team should be in professional attire. This includes dress pants, dress shirts, a suit, dress shoes, and professional blouses and skirts.

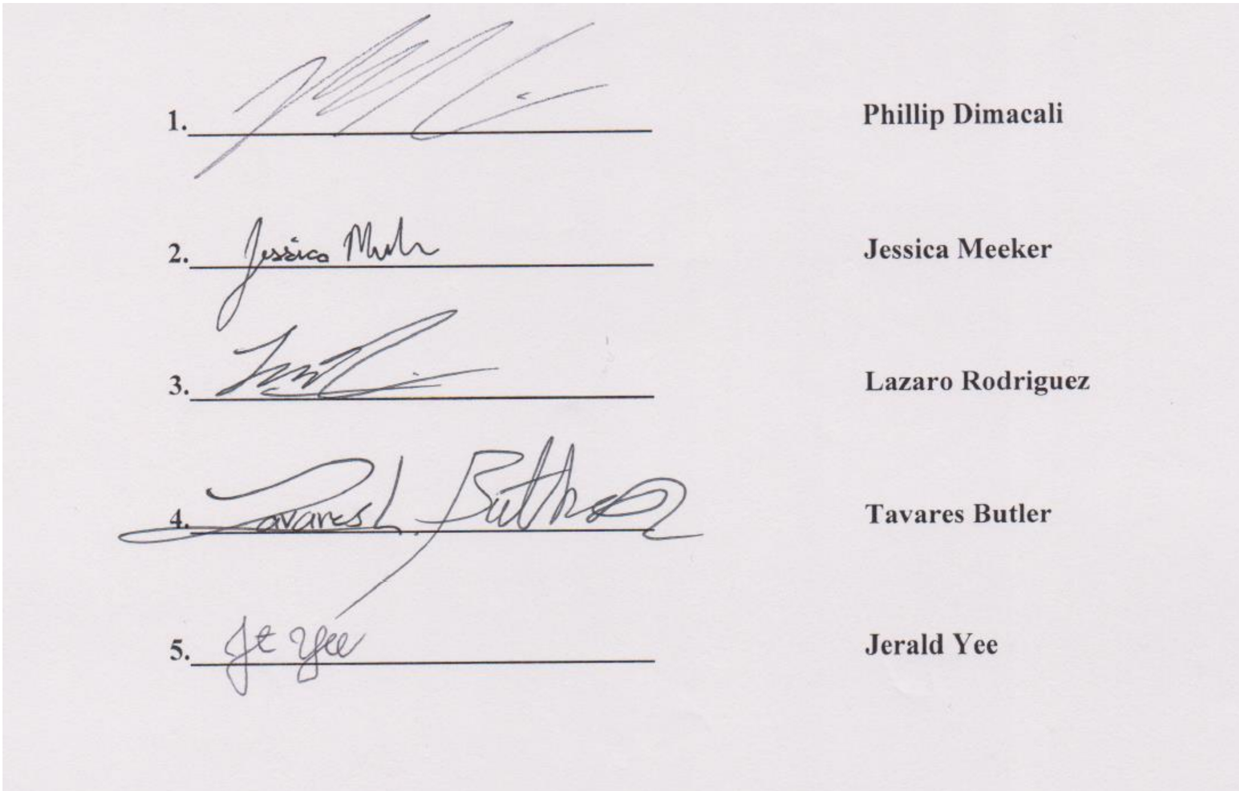
Attendance Policy:

Each team member is expected to participate in all meetings and to arrive on time. Team members should notify the team if they must miss a meeting due to an emergency, scheduling conflict, etc.

Decision Making and Conflict Resolution:

Decisions that are critical to the outcome of the project and/or are controversial between group member concurrences will be analyzed and decided with a unanimous vote. Additionally, all group members are encouraged to be open and honest regarding any current or potential issues they may have with the project and its affiliates.

Team Member Signatures



1. Phillip Dimacali

2. Jessica Meeker

3. Lazaro Rodriguez

4. Tavares Butler

5. Jerald Yee

Appendix B: Functional Decomposition

Figure B22 Complete Rover Functional Decomposition Flowchart

Appendix C: Target Catalog

Table C39

Target Catalog

Metric	Target
Amount of fixture points	4-point restraints
Mobility allowed	Extremities
Time	20 seconds
Mobility allowed	Extremities
Height, weight	5'0" to 6'4" Maximum weight capacity 400 lbs total
Angle of protection	180 degrees
Angle of vision	360 degrees
Clearance	At least 1 inch
Clearance	At least 1 inch
Suspension travel	7 inches
Suspension travel	7 inches
Factor of safety Length of misalignment	2 < 0.01 inches
Type of input	Pedal power Hydraulic braking Mechanical steering
Type of output	Torque to wheels Orientating steering system
Types of bearing, gear, sprocket, chain, etc. fitments	ANSI, AGMA, SAE standard fits
Suspension Travel	7 inches
Suspension type	Coil spring & damper
Rider component height	14 inches
Suspension type	Coil spring & damper
Rider component height	14 inches
Rider approval	100% approval
Center of gravity	Relatively low
Type of suspension	Long-travel, coil spring & damper
Factor of safety	2
Number of shaft supports	2
Length of misalignment	< 0.01 inches
Clearance	1 inch
Factor of Safety	2
Type of fixing	Through bolt
Rider Component height	14 inches
Number of restraint fixtures	4
Turning radius Type of brakes	15 foot hydraulic
Type of transmission	Variable torque
Type of transmission	Concealed, recessed components
Length of misalignment	< 0.01 inches
Type of mate	Weld, through bolt
Turning radius	15 feet
Type of transmission	Variable torque

Unloaded Weight	200 lbs
Drivetrain Torque ratio	Variable
Total Cost of Vehicle	< $2000
Unassembled cubic volume	48 square inches

Appendix D: Work Breakdown Structure

Table D40

Team 514 Work Breakdown Structure

PROJECT CHARTER	**DUE: SEP 20, 5 PM**
Assignment meeting	Entire team
Scope	Entire team
Mission statement	Lazaro
Team roles	Jessica
communication	Phillip
Dress code	Tavares
Attendance policy	Jerald
Statement of understanding	Entire team
Submission	Tavares
WORK BREAKDOWN STRUCTURE	**DUE: SEP 20, 5 PM**
List evidence book milestones	Jessica
Tasks	Tavares
Assignee	Phillip
Tasks are detailed to completion	Jerald
Submission	Tavares
CUSTOMER NEEDS	**DUE: SEP 20, 5 PM**
Team scheduling	Jerald
Rubric Review	Entire team

Develop statement/need table	Lazaro
Develop interpreted needs	Jerald
Develop high-fidelity needs	Phillip
Proofread/Editor	Tavares
Submission	Tavares
FUNCTIONAL DECOMPOSITION	**DUE: SEP 27, 5 PM**
Team scheduling	Jerald
Rubric Review	Entire team
Competition guidebook review	Entire team
• HPV weight limit • Wheel design regulations • Drivetrain design regulations • Obstacle and Task breakdown • Scoring system analysis	
Decompose functions	Tavares
F.D. cross reference table	Phillip
F.D. Chart	Phillip
Explanation of Results	Tavares
Connection to Systems	Jerald
Smart Integration	Jessica
Action and Outcome	Jessica

Function Resolution	Lazaro
Proofread/Editor	Tavares & Phillip
Submission	Tavares
VDR1 SEP 30	Entire team
Team scheduling	Jerald
Project Background	Jerald
Project Scope	Tavares
Market/Stakeholders	Lazaro
Custom Needs	Jessica
Functional Decomposition	Phillip
Submission	Tavares
Targets	**DUE: OCT 4, 5 PM**
Team scheduling	Jerald
Rubric Review	Entire team
Assign each function a target	Lazaro
Address additional targets, disregarding functions	Jerald
Validate targets	Phillip
Discuss derivation	Tavares
Tools of measurement	Jessica
List critical targets and metrics	Phillip
• Consult competition guidebook • Compare tasks to required regulations • Compare additional targets to point	

breakdown	
Summarize targets with catalog	Jerald
Submission	Tavares
VDR1-REV2 OCT 7	Entire team
Team Scheduling	Jerald
Previous VDR1 review	Jerald
Targets	Phillip
Metrics for success	Lazaro
VDR1 SUBMISSION	Entire team
PEER EVALUATION	Entire team
CONCEPT GENERATION	**DUE:**
Team scheduling	Jerald
Rubric Review	Entire team
"100" Concepts	Entire team
Specialized Drivetrain Concepts	Phillip
Specialized Wheel Concepts	Phillip
5 Medium Fidelity Concepts	Tavares
3 High Fidelity Concepts	Jessica
Concept Generation Tools	Jerald
Proofread/Editor	Phillip & Tavares
Submission	Tavares
CONCEPT SELECTION	**DUE: OCT 25, 5 PM**
Team scheduling	Jerald

Rubric Review	Entire team
House of Quality	Lazaro
Pugh Chart	Phillip
AHP	Jerald
Reiteration	Phillip
Final Selection	Entire Team
Proofread/Editor	Jessica
Submission	Tavares
SUBMIT VDR2	Entire team
Team scheduling	Jerald
Concept Generation	Jessica
Key targets(Wheels and Drivetrain)	Phillip
House of quality	Tavares
Pugh Chart	Jerald
AHP	Lazaro
Concept selection	Lazaro
BOM	**DUE:TBD**
Team scheduling	Jerald
Material selection	Lazaro
Material Review	Jessica
PEER EVALUATION	Entire team
RISK ASSESSMENT	**DUE: NOV 15, 5 PM**
Identify potential hazards regarding our project	Tavares

Research safety hazards and site primary source	Phillip
Develop contingencies	Jerald
Develop safety measures and personal protection, procedures, etc.	Lazaro
Identify emergency responses	Jessica
Identify emergency contact	Tavares
Submission	Tavares
SPRING PROJECT PLANNING	**Due: Nov 22, 11:59 PM**
Timeline	Entire team
Milestones	Entire Team
Deliverables	Entire Team
Submission	Tavares
VDR3 NOV 25	Entire Team
SPONSOR AND ADVISOR EVAL	Entire Team
VD3 POSTER	Entire Team

Work Breakdown Expectations

Table D1, the team work breakdown structure, is to be reference by team members; the work breakdown structure is not to be followed necessarily verbatim. However, it gives the team a sense of individual responsibility.

Although every team member is expected to contribute a fair share of work (see code of conduct), this work breakdown structure creates a lead in the event any tasks are not being completed or the work is below the team standard set in the code of conduct.

Appendix E: Generated Concepts List

Table E41

Generated Concepts List

HF - High Fidelity Concept

MF - Medium Fidelity Concept

#	Concept	Description
1.	Independent Suspension Fork	4-bar linkage suspension for each wheel, spring damper strut, single moment input.
2.	Chain Ring Rear Legs	Accepts moment input, transmits torque through chainring to wheels. Rotates about chassis, suspended by spring damper.
3.	Pedal driven gearbox system	Pedal into gearbox, shaft drive, into gearbox, then to wheels.
4.	Foam core wheel	Metal hub, fiberglass shell, rubber tread, structural foam core.
5.	Rigid bi-wheel fork	Front rigid fork accommodating two wheels.
6.	Ski fork	Rigid fork with two suspended skis on either side.
7.	Elevated driver layout	One driver, sitting forward, provides propulsive power; the other sits aft elevated steering.
8.	Tricycle	Two wheels aft, one front.

9.	Rigid bike	Rigid suspension.
10.	CVT transmission	Incorporating a CVT into drivetrain.
11.	Tracks	Utilizing linked tracks in drivetrain.
12.	Differential	Incorporating a differential into drivetrain.
13.	Integrated Suspension Wheels	Wheels that incorporate suspension parts and potential energy.
14.	Pneumatic wheels	Wheels that utilize air pressure.
15.	Linkage steering	Achieving mechanical manipulation by using a linkage system.
16.	Hydraulic steering	Integrating hydraulic, lines, and rams into the rover system.
17.	Leaf springs	Suspending wheels using leaf springs.
18.	Rear Steering	Steering vehicle from rear wheels like a forklift.
19.	Double input drivetrain	Accepting work from both drivers into propulsion system.
20.	Hydraulic braking	Using hydraulic lines, and rams in braking.
21.	Cable braking	Using cables in braking system.
22.	Tricycle Sled	Two rear wheels drive a snowmobile like front sled.

23.	Tricycle Sled	Two rear wheels drive a snowmobile like front sled.
24.	Single Sled	One long sled down the middle with two wheels providing power.
25.	Sideways trike	Two wheels on the right side with one wheel on the left side.
26.	Diamond shape	One wheel in the front and back, two wheels on each side.
27.	Built in wheel suspension	Spokes have some built in suspension to absorb impacts on the rim.
28.	Prone harness	Harness to secure one rider in a prone position for steering and tasks.
29.	Leg sled propulsion	Rigid sled is pushed back and forth by riders to supply power to an axial.
30.	Sled training wheels	Sleds fashioned on each side of a wheel for stability.
31.	In-line seating	Seating for both riders in a straight line
32.	Alternating in-line seating	Both riders are seated in a line facing different directions.
33.	Side by side seating	Both riders are seated next to each other.

34.	Suspended steering	A wheel is suspended off the ground, the driver pushes the wheel down at desired angle turning the vehicle.
35.	Multi-segmented body	Body separated by parts to allow quick assembly/disassembly and individual suspension.
36.	Fluid filled wheels	Non-compressible fluid used as wheel structure.
37.	Elliptical power	Rider moves paddles up and down to produce power to axial.
38.	Steam roller front wheel	One, long wheel to smooth out small obstacles before vehicle passes over.
39.	Pedal steering	Mechanical linkages controlled with the riders feet.
40.	Row power propulsion	A bar can be pulled or pushed to generate motion. Could add to pedal power.
41.	Soft tire treading	Soft treads absorb some impact.
42.	Rope steering	Like a sailboat. Pull on the rope to adjust the position of front axle.
43.	Metal rimmed-rubber edged wheels	Wheel is a metal hub with rubber tread.
44.	Metal rimmed -track	Wheel is a metal hub with tracking tread.

45.	Two independent frames	Vehicle is separated into two halves that can rotate independently depending on surface.
46.	Wood wheels	Solid wood wheel hub with wood framing.
47.	Double Input-Sideways seating	Pilots sit side by side with both driving inputs.
48.	Single Input-Sideways seating	Pilots sit side by side with a single input.
49.	Metal rimmed - metal tread	Wheel is a metal hub with metal tread.
50.	Segmented double ski	Skis on the side of the rover that are segmented.
51.	Double standing pedal and single steering	Riders pedal while standing and one rider steers.
52.	Single standing pedal and single elevated sitting steering	One rider stands and pedals, while rider in the rear sits elevated and steers
53.	Reverse seating double input	Riders sit with their back towards each other and both pedal.
54.	Reverse seating single input	Riders sit with their back towards each other and one rider pedals.
55.	Two wheels double input	Bicycle with both riders pedaling.
56.	Two wheels single input	Bicycle with one rider pedaling.
57.	Retractable seating	Riders can retract their seats back and forth for greater power.

58.	Aluminum framing	Vehicle is made out of lightweight aluminum.
59.	Metal-wood-rubber wheels	Wheels have a metal hub, with wood framing, and rubber treads.
60.	Double steering	Riders have the option to control/ share the steering.
61.	Sitting and laying seating - single input	The rider sitting will power the vehicle, while laying rider will complete obstacle tasks.
62.	Double input- weight shift steering	Both riders will pedal while shifting their weight to either side of the rover to turn.
63.	Ski-Prone Pilot (MF)	Rider is prone rotating front ski to steer vehicle with the second providing power to the rear axle.
64.	Built in Tire Suspension (MF)	Spokes are jointed to allow compression; A spring damper is in between the linkages in order to absorbs some energy.
65.	Sideways Trike (MF)	Two wheels on one side, with adjustable rider position.
66.	Prone Pilot Tricycle (MF)	Driver is secured by a harness in the prone position. Second rider drives the rear axle.

67.	Diamond Rover (MF)	Wheels positioned in a diamond pattern with rear rider provides power.
68.	Rigid Bi-Wheel Fork (HF)	Accepts an input from a four-bar crank-rocker steering system.
69.	Ski Fork (HF)	Utilizes two skis along each side of the central wheel.
70.	Single Input Driver Layout (HF)	One driver provides propulsion through pedal power; the other is slightly elevated in the rear steering.
71.	Solid-Axle Double-Input Drivetrain (HF)	Utilize chain drives for driver input; there will be no torque manipulation.
72.	Foam Core Wheel (HF)	A metal hub, containing bearings, a fiberglass shell, rubber treads, and an injected foam core for structural support.
73.	Independent Suspension Fork (HF)	Allows for small, required turning radius as well as vibration and impact dampening.
74.	Linkage Drivetrain (HF)	Two cranks are coupled on each side to form a four-bar double crank mechanism.
75.	Filtered Lens	Interchangeable lens housing the colored filters.

76.	Hand-held Filters	Holding the filters in front of the camera with riders' hands.
77.	Digital Filters	Digitally apply colored filters
78.	Cell Phone Camera	Use of the rider's cell phone camera to take the filtered photos.
79.	Custom Variable Viewfinder (HF)	Device attached to a camera that allows the colored filters to be changed with ease.
80.	The Simple Circuit	Crude but cheap and effect circuit containing the needed materials.
81.	Deployable Solar Cell (HF)	Compact device used with the ability to detect sunlight, housing a compass to allow for proper orientation deployment.
82.	Compass Circuit	The simple circuit built around a compass.
83.	Easy Out	Connect components only using wires, crude and un-innovative but cheap.
84.	Over Kill	Elaborate housing unit that is water and dust resistant.
85.	LED Power Indicator	Use off multiple LED to indicate how much power is being drawn in by the photovoltaic cell.

86.	Core then Store	Use of a commercial coring device and storing it in a collection bin afterwards.
87.	Core Retriever (HF)	Originally designed device to collect a core sample and store in the same unit, while still allowing analysis of the internal contents.
88.	Bore and Store	Use of a conical boring device that upon closing resembles a cone while housing the collected sample.
89.	Adapted Corer	Adaptation of a commercial concrete coring machine to be used on softer materials and with slurries.
90.	Vacuum Corer	Use of suction to pull the cored contents into a storage cylindrical container.
91.	Plastic Sleeve	Plastic cylindrical sleeve to act as the storage device for the contents gathered.
92.	Cap n' Go (HF)	Adaptation of an extended grabbing device altered to hold a cupping and sealing mechanism that allows for collection and storage in one collection attempt.

93.	The Dino Grabber	Use of the Dino grabbing toy to grab the solid materials and released into a storage contain.
94.	Trash Picker Upper	Adapted trash collecting device to be able to collect liquid and solid materials of various volume.
95.	Extended Scoop	Creation of a scooping device with the ability to extend to prevent the need of the rider to leave the vehicle.
96.	Vending Capsules	Use of vending capsules to act as the collection and storage container for collection devices. Prevents cross contamination.
97.	Custom Capsules	Originally designed capsules manufactured to act the storage device that can be used during sample collection. Attached to one of the collection devices. Prevents cross contamination.
98.	Rover mounted collection bins	Storage containers of sample collections are attached to the frame of the rover to allow for easy storage.

99.	Rider Mounted collection harness	Utility strap worn by the rider to hold the collected samples held in the storage capsules.
100.	Ladle and Rinse	Use of a common kitchen ladle to scoop the collection materials and rinse after each collection sample to prevent cross contamination.

References

There are no sources in the current document.