HERC Vision Builder Adventures Rover Challenge Team

DESIGN REVIEW REPORT 2021

JANUARY 12

VBA Rover Challenge Team

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Design Readiness Review Report 2021

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Abstract- This Report serves to provide insight into the construction of the Vision Builder Adventures Rover (VBAR). The VBAR is a Rover built to compete in the 2021 Rover Challenge Competition in Huntsville, Alabama. In 2020, the Vision Builder Adventures Rover Challenge Team (VBA RCT) were charged to use the engineering process to design, build, test, evaluate, and compete in the 2021 Human Exploratory Rover Challenge (HERC). In the HERC, all teams competing must create a Rover to fit certain criteria, and perform different tasks.

INTRODUCTION

This Report serves to provide insight into the construction of the Vision Builder Adventures Rover (VBAR). The VBAR is a Rover built by students to compete in the 2021 Rover Challenge Competition in Huntsville, Alabama.
In 2020, a select group of Vision Builder Adventures students were charged by Vision Builder Adventures to design, build, test, evaluate, and compete in the 2021 Human Exploratory Rover Challenge (HERC). In the challenge, each team had to create a rover to fit within the HERC criteria. The specific areas to consider:

- Distance- The miles the rover would travel under a load(drivers).
- Durability- The strength of the frame to handle the obstacles under a load.
- Cost- Expenses of the parts along with the amount of time it would take to fabricate.
- Maintenance- choosing durable parts(components) that require very little maintenance after fabrication.
- Weight- The complete weight in pounds must meet the HERC criteria.
- Comfort- the comfort for the passengers as they traverse through different terrains.

DESIGN TEAM DRAFTING

In this section, there are 3 main designs for the frame, drivetrain, and seating arrangements. Out of the three designs, 2 designs resemble a 2-person bicycle, and another where the 2 drivers are sitting side by side. Each design is considered for its practicality (cost and functionality).

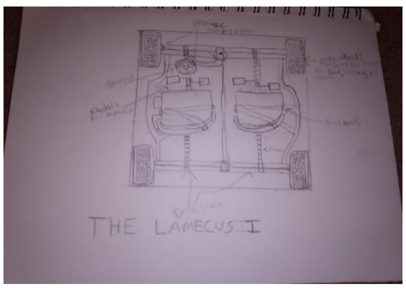
FRAME DESIGN

The first design was a “side by side design” created by Marshall George. In this design, both drivers are facing the front with both drivers pedaling in the same direction and on the same Drivetrain. The Drivetrain has 2- horizontal bottom brackets and a vertical chain to the rear tires. The benefit of this design is it will not need to collapse. It would easy fit with in the 5 X 5 Criteria. The issues would be stability with all the weight put on the back. Poor center of Gravity. Too much weight would cause the front to lift up. Poor stability could make it harder to control over obstacles. (Reference 1)

The second design was the “back to back design” created by Major George. The “back to back design” has a two-driver vertical drive train system. The benefit of this design is it has a 4-wheel drivetrain system (4X4). 4-wheel drivetrain means power to both axles. Meaning all four wheels are powered. Another benefit to the design is the center of gravity. All weight (load) is at the center of this Rover. This will make the Rover more stable going over obstacles. The issue with this Rover is the vertical length. Rover would be 7-8 foot in length. The length would not fit with in the 5X5 HERC parameters. The length would require us to collapse the Rover. The issue would be collapsing the Rover at the center of its gravity point. With the load in the middle. The collapsing bracket (Fastener) would become the structural point of weakness. Another issue/concern with this design is the drivers facing in the opposite direction. The rear driver has no frontal vision on the course. The concern is communication. The front driver would have to call out obstacles and understand how the rear wheels may have delayed controls. (Reference 2)

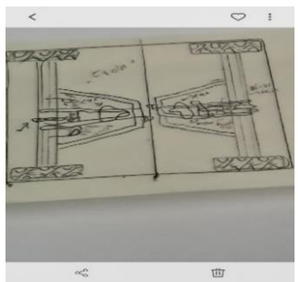
The third and final design was a “frontal linear design” created by Jacob Kim. This is a frontal design because both drivers are facing to the front. This design makes communication easier. Its vertical design makes it more aerodynamic. This design also off-sets the center of gravity with the two drivers (One in the front and one in the back). The off-set would put less weight on the collapsible fastener when locked into place. The issue with this design compared to the “side by side design” is the power. This design only powers one axle (meaning 2 wheeled drive). (Reference 3)

Reference 1



Side by Side

Reference 2



Back to Back

Reference 3

Frontal Linear

Design Selection

In this section, we will see which Rover design was selected and why. The design criteria we had to consider was; (1) Rover has to fit in a 5ft X 5ft volume box before the competition. (2) It must be able to seat two drivers, one of each gender. (3) Specific weight requirement. Rover needs to weigh less than 130 pounds. (4) Rover needs to be assembled in 2 minutes. (5) Rover clearance should be 12 inches between the ground and the lowest point of the Rover frame or subsystem.

We decided against the “side by side design” because it was less aerodynamic and would have challenges further with the weight requirement and clearance requirements. We chose against the “back to back linear design” based upon on the weight on fastener issue. We selected the “frontal linear design” (FLD) because it was more aerodynamic, and the design could help us meet the requirements of size, weight, volume, and clearance.

Rover Design Blueprint

In the HERC, the following requirements were established in order to compete in the competition. These requirements were size, weight, volume, assembly, and clearance. To meet the requirement of size, volume, assembly, and clearance, we chose to collapse our rover. To meet the requirement of weight, we needed to consider the frame composite.

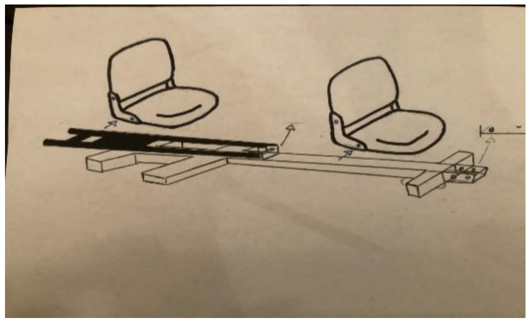
Meeting HERC Design Requirements

With our “frontal linear design” we looked at a few different ways to collapse our rover. (Reference 4) One design was with a Fastener (Hinges) in the middle of the rover. Another design with swinging hinges from a solid frame. (Reference 5) We chose neither.

Reference 4

Fastener/Hinge/Bracket

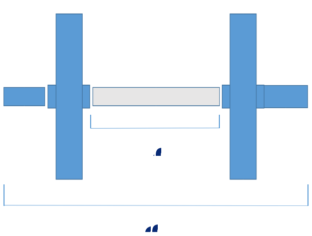
Reference 5



Swinging Hinges

The final design was an internal collapse within the rover. Upon fabrication of the rover, we decided to go with the collapsing within design. The hinge design has 2 fastening points to connect the frame. The fastening points are connected by screws. These screws become potential failure points with added driver weight. The hinge would also not help with the rover’s overall weight. The frame that was chosen has a hollow steel shaft with an aluminum shaft within the hollow steel shaft. (Reference 6) The aluminum shaft helped to eliminate a lot of weight and gave us the ability to collapse the rover to meet the size constraint. The rover is 8 feet long, but when collapsed is reduced to four feet. (Reference 7-8) This easily fits within HERC’s size constraint. We inserted a piece of aluminum inside of a hollow steel frame which eliminated over approximately thirty pounds of weight and enabled it to fit within the HERC requirements. The volume and constraint HERC requirements were met with the linear design construction. Our tires enable for us to have the proper clearance from the ground. Our linear design ensures that the volume criteria is met as well.

Reference 6



Reference 7

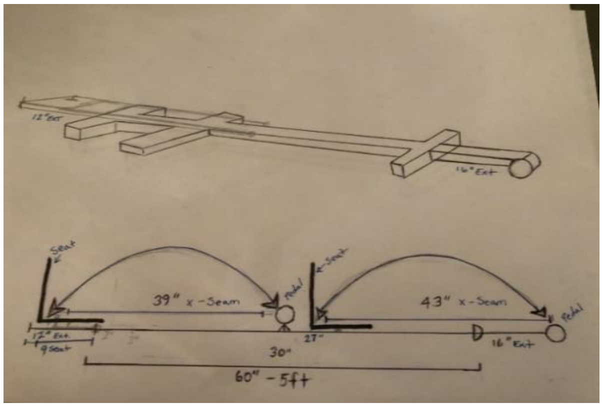
Reference 8

Rover Design System Levels

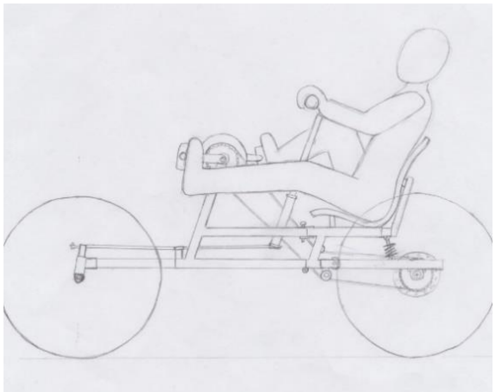
Drive Train Systems

The HERC drive train requirement mandates us to come up with a two-passenger powered rover. In our initial drive train designs, we were going to use hinges to extend the drive train to accommodate the passengers x-seams (Reference 9) (a measurement from the sitting position of a person with legs outstretched, and is the distance from the lower back to sole of feet) (Reference 10).

Reference 9

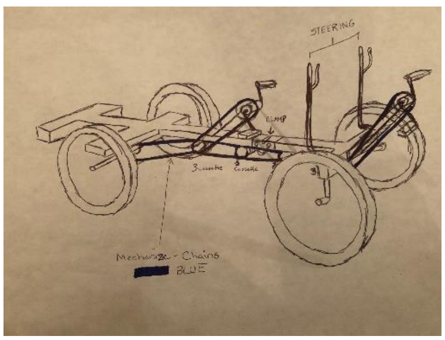


Reference 10

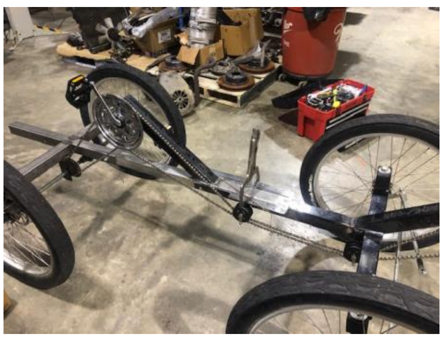


However, we decided to make an adjustment with the seating which helped lengthen the x-seam compacity. So, we welded the bottom brackets onto protruding angled rods from the frame. The rods were welded in place to become a piece of the frame. We also decided to do a detachable seat which would enable us to meet the HERC size criteria and make the rover comfortable for the occupants (Reference 11). To power the drive train, we decided to use a chain system very similar to a recumbent chain system. The chain system consisted of crank sets and bearings installed into our bottom brackets. We also used idlers to extend the chain and collapse the chain where needed. The idlers help us to ensure maximum torque on the chains. (Reference 12)

Reference 11



Reference 12



Suspension System

In the HRC, they had little to no specific requirements for rover suspension. Upon building the suspension system, it was decided to use a C-clamping system. (Reference 13) The C-clamping system is a system used with small work trailers that give you a higher compacity than a wheel barrel. The initially added suspension within the seating brackets to provide comfort for the passengers. (Reference 14) Upon testing the rover, it was found that the seat suspension hindered the driver’s ability to increase torque on pedals. So, the suspension was removed from the seats. The only suspension that the Rover has is the C-clamp spring suspension system.

Reference 13

Reference 14

Steering System

One of the most important subsystems to the Rover is the steering system. The Steering system is just as important as the Drive Train System. Without steering it would be impossible to navigate around obstacles. The Steering System that was chosen was based upon the C-clamping system used for suspension. The C-clamping system is used with Go-karts, it provides a 45-degree turning radius and is very durable. (Reference 15)

Reference 15

Braking System

In this section, we will talk about the braking system. A good braking system will be essential to the rover’s performance in this event. The ability to slow down or stop at critical times is important, throughout the course. So, selecting the best braking system is critical to competing in the HERC. The braking systems considered for this Rover were Drum brakes, Rim brakes, and Disc brakes.

Drum (Coaster)Braking system

There are two types of bike tire hubs, the Free wheel and the Coaster hub. The Free wheel hub needs an external braking system on the wheel itself to stop. The Coaster hub has a brake mechanism within. (Reference 16)
The Coaster Brake is a brake that is engaged when pedaling in reverse. The brake is enabled within the rear tire hub. The problem with this braking system is in gearing performance as it relates to drivers. This Hub is normally used on kids bikes or cruiser bikes. It's not a racing hub. Without a Free Wheel Hub, the pedal is not free to spin. This will affect the speed of the Rover.

Reference 16

Coaster Brake

Rim (Padding)Braking system

The Rim braking system is an external braking system. The brake is placed over the Rim, and once applied it provides fiction causing the Rim to stop. The problem with this braking system is mounting to non-traditional tires. (Reference 17)

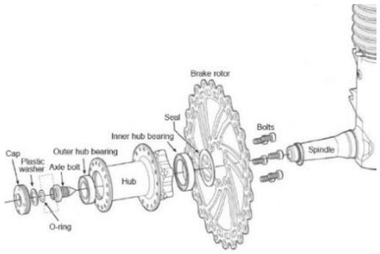
Reference 17

Padding Braking system

Disc Braking system

The Disc braking system is a braking system commonly used on Motorcycles. This braking system is also used on mountain bike. The Disc braking system is durable and resistant to mud and water. This braking system is separate from the Rim so no damage can be done to the Rim. (Reference 18) The Disc braking system is the one that was chosen.

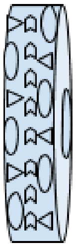
Reference 18



Wheel Design System

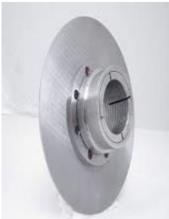
In designing our Wheel Design, we focused on durability, stability, and traction. Initially, 3-D printing a wheel was the idea. The idea was developed with weight in mind. The wheel that needed to be created needed to be light weight and durable. During Zoom Calls with professionals about the most effective 3 D printing materials, (MC Poylmers) we determined Nylon was the way to go. We met with 3-D printers. It was determined that no company in our area could print our Full-sized (30') Rim. It was then determined that the Rim could be built in parts. Upon viewing previous Rover Challenges, some 3-D printed wheel failed during competition. The 3-D printed parts increased the failure potential of the wheel. The joints becoming a stress point. The joints are normally fastened by Screws or Glues, making the joints points weak. The type of wheel chosen was a design by Marshall. (Reference 19) The Rim will be made out of Aluminum. Aluminum was chosen because of the durability. With the aluminum we can weld into a one-piece Rim. By creating a one-piece Rim, it eliminated fasteners. This wheel also appears to be a competitive wheel design from previous Rover Challenges. First, we fabricated the Hub. (Reference 20) The Hub had to be machined down to a size that fit the stem. Once completed, it was welded within a laser cut disc. (Reference 21) Lastly, a brim was added to the outside of the Disc. (Reference 22) Once assembled the tire was 30" X 2". The 30" provided the clearance over obstacles needed. The 2ft width helps stabilize the Rover for all terrains. (Reference 23) Our only concern with the Rim was weight. Upon fabrication we added holes within the Aluminum rims to reduce the weight. For traction, rubber strips were baked on by local company. We added a pattern to the rubber strips for more traction.

Reference 19



Reference 20

Reference 21



Reference 22

Reference 23

OTHER MISSION TASK TOOLS

In this section, we will talk about the other tools that will be needed to complete task. The HERC is not just an obstacle course. Additional tools are need to complete task.

Tools for Obstacle course

The required tools that will be deployed during the challenge are; Camera with 3 light filter, a solar powered light source, a retrieval device for collecting soil samples, water samples, and lastly a container for storage of retrieved materials.

- The Camera used will be a 15 Mega Pixel Camera 3 light filter for the Spectrographic Analysis.
- The Solar powered light source was created for Instrument Deployment.
- Long handled scooper tool created out of PVC to collect 3 samples for 3 different tasks. (1) Core sample, (2) 3 different textured soil samples, and (3) 3 liquid samples.

Tools for Communication on mission

There are two communication tools that will be used during the Mission. The tools are a Go Pro camera, and a Head set. The Go Pro will be attached to the 1st drivers Helmet. This tool will give us a visual of the obstacle course in real time. Lastly, the driver will have an Ear piece to communicate with the Pit Crew chief should a problem occur.

MISSION PERFORMANCE PREDICTION

Preparation for the course

To prepare the Rover to take on the HERC, testing was done. The Rover was tested at our local BMX track. At this BMX Track we tested for the following HERC obstacles. The Transverse incline, the High Butte, Undulated terrain, Ice Gayser Slalom, Lunar Crater, and the Sand Dunes. At the BMX track the Rover performed well structurally. The Frame hollow collapsing with-in capabilities was the biggest concern in testing. The frame was twisted and pounded. The track had a number of climbs, bumps and jumps. The Transverse incline, the High Butte, and Undulated terrain all put major stress on the frame. But we feel good about our success with these obstacles. The Track was also a little muddy in spots. This condition made drivers traverse cautiously using brakes and steering at time to complete course. The Ice Gayser Slalom, Lunar Crater, and Sand Dunes requires braking and steering disciple with the drivers. We also feel comfortable with this obstacle as well. Therefore, we predict success on these six obstacles.

To prepare for the other terrains the tire becomes the focal point. The tire created was based on the challenges of 7 obstacles. (1) The Crater with Ejecta, (2) Tilt Crater, (3) Loose Regolith, (4) Pea Gravel, (5) Bouldering Rocks, (6) Large Ravine, and (7) Crevasses.

The Crater with Ejecta, Tilt Crater, Loose Regolith, Pea Gravel, all deal with loose material. The tire we have constructed have grip designed to pull through these obstacles. The tires will be tested on gravel surfaces at shop (driveway (loose gravel)) before the HERC. The Boulder Rocks obstacle requires grip as well, but durability of the wheel is crucial for this obstacle. This will also be tested at the shop. Lastly, the Large Ravine and the Crevasses are obstacles in which the tire size will be an issue. The tire size is 30” which will enable us to pull over the Large Ravine, and the clearance to go over the Crevasses obstacle. We predict success on these 7 obstacles as well.

Upon review of these obstacles we will continue to test up until March. There is no doubt that the VBA RCT will be ready for the challenge.

Safety

To compete in the HERC 2021 Race there were a lot of things to consider. Two of the biggest components considered in this Adventure were with time, and cost.

Time Management

Time management is a significant part of this project. When you working with so many people with different schedules, time management is critical to getting the project completed. Poor time management could cause delays into a project that could be costly. For instance, an untimely customized part backorder could sink a project under time constraints.

Cost

Secondly, the biggest component is cost. The project does not get off the ground without financial backing. The price of building a customized vehicle and testing it for a race can be an enormous cost, without financial management it would be impossible. (See Rover cost projections below. (Reference 24))

Reference 24

2021 Projected Financial Rover Cost

VBA Rover Components	
Frame (Steel and Aluminum shaft)	$2,500
Drive Train System Components	$1,000
Braking System Components	$500
Steering System Components	$500
Wheel System Components	$2,500
Other misc. Rover Parts	$100
Projected Total Rover Cost	$7,100

Hazard Analysis

Below is the Hazard Analysis chart used to review every obstacle at the HERC. Within the Analysis chart, the Specific Hazard is displayed, along with the Personal Protective Equipment used to protect each driver. The Rover control were also analyzed for personal safety over each obstacle. (Reference 25)

Reference 25

Task at HERC	Hazards	Controls	Personal Protective Equipment (PPE)
The Crater with Ejecta	Crater	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Tilt Crater	Crater	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Loose Regolith	Loose Materials	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Pea Gravel	Loose Materials	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Bouldering Rocks	Loose Materials	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Large Ravine	Loose Materials	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Crevasses	Cracks	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Transverse incline	Incline	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
High Butte	Incline	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Undulated terrain	Navigational	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Ice Gayser Slalom	Navigational	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Lunar Crater	Navigational	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,
Sand Dunes	Navigational	Steering and Suspension	Seat Belts, Padding, Helmets, goggles, gloves,

Failure Modes and Effects Analysis (FMEA)

Below is the FMEA chart used to help produce success at the HERC. Within the Analysis chart, failure of potential hardware of the Rover is analyzed. Failure mode, failure causes, and stress is considered, along with how to potentially mitigate. (Reference 26)

Reference 26

Hardware	Failure modes	Failure cause	Stress	Mitigate
Frame	Hollow Frame	Twisting of frame	uneven surfaces	Travel through slowly
Drive-Train	Chain	Chain breaking	Inclines	New Chain
Steering component	Steering radius	loosing control	Going to fast around obstacle	Slow travel though obstacle
Braking System	Unable to stop	Disc brake failure	Loose material obstacles with potential declines	Slow travel though obstacle
Wheels	Integrity of wheel	Hitting a large object	Large Boulders	Move at a moderate pace
Suspension System	Spring	Heavy pounding	Large Boulders, Bumpy surfaces	Move at a moderate pace
Seats and seat belts	Disconnecting from frame	Twisting of chairs	Uneven surfaces	Travel through slowly

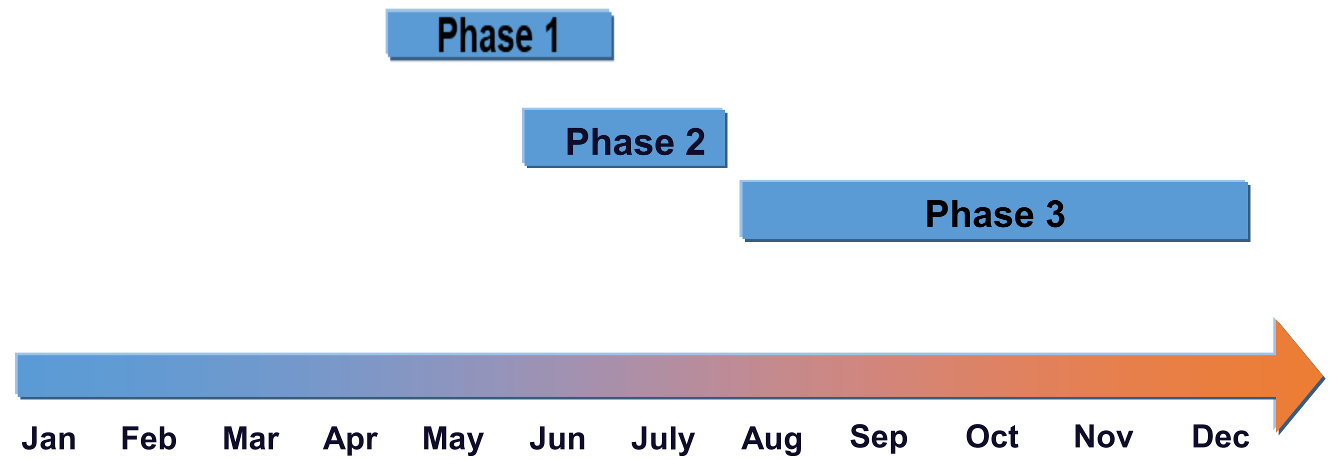
Project Plan

The project began on Wednesday June 24, 2020. The selected students met with the project leaders via Zoom to talk about expectations and the Project scope. The project scope was the time frame in which we will use to complete different goals. Each goal completion will lead us to our ultimate goal. Racing and winning the HERC in April 2021.

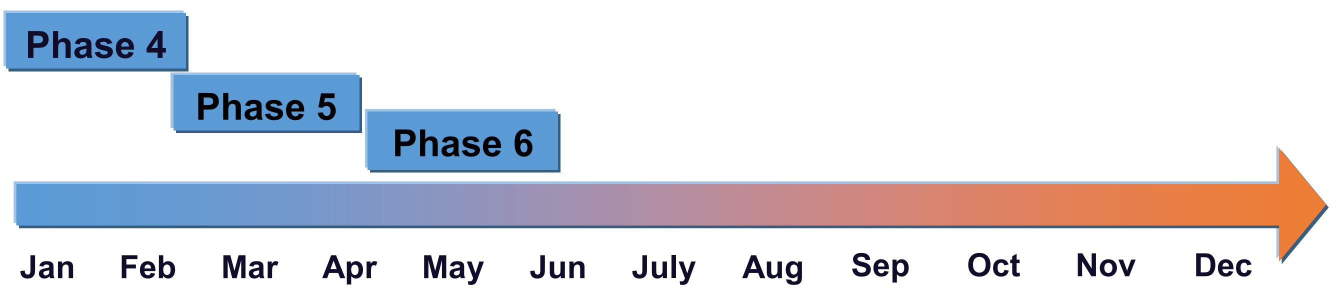
The Project Scope consisted of 6 Phases: Phase #1: Initiate, Phase #2: Reconnaissance, Phase #3: Fabrication and Review, Phase #4: Final Scope, Phase #5: Ready Forward, Phase #6: The Race. (Reference 27)

Reference 27

2020 Timeline Graph



2021 Timeline Graph



Phases Description

Phase 1 Initiate (is the Brainstorming Sessions), Phase 2 Reconnaissance (is the Research and Design), Phase 3 Fabrication and Review (Build and test), Phase 4 Final Scope (is Reporting), Phase 5 Ready Forward (is Project completion), and Phase 6 The Race (is HERC Event).

Timeline Review status with Phases

Phase 1 Initiate

In the Brainstorming Sessions, each student was challenged to watch a Rover Challenge competition and design their Rover and write a Report about their Rover. The Reports were due on Saturday, July 11, 2020. The Design had to comply with the 2020 HERC guidelines.

Phase 2 Reconnaissance

On Tuesday, July 14, 2020 the students had a Zoom call with the Engineers at MC Polymers. On the call, engineers collaborated with students on practical design ideas. The engineers reviewed student ideas and shared insight from wheel composition to frame composites. Afterward, student design was chosen.

Phase 3 Fabrication and Review

On Saturday, July 25, 2020, we met with MOBS Fabrication (Shop) to talk about a building and testing schedule for Phase 3. Rover parts from local bike re-cyclery were also delivered.
On Saturday, August 8, 2020 final Rover parts were delivered to the shop.
On Saturday August 15, 2020, all students had a Zoom call with resident engineer to discuss Mechanical Engineering and HERC Terminology.
On Saturday August 29, 2020, students meet at the shop, were the were taught about Safety guideline and the tools and equipment that will be used. The students also began the building of the Rover (Frame Collapsing).
On Wednesday September 2, 2020, Fabrication Students had a Zoom call to discuss progress.
On Wednesday September 16, 2020, Fabrication Students had a Zoom call to prepare for Saturdays project build.
On Saturday September 19, 2020, Students meet at the shop, the Fabrication Students worked on the Rover (Frame Collapsing and Seating alignment).
On Thursday October 1, 2020, Fabrication Students had a Zoom call to prepare for Saturdays project build.
On Saturday October 3, 2020, Students meet at the shop, the Students worked on the Rover (Suspension and Steering System).
On Thursday October 8, 2020, Fabrication Students had a Zoom call to prepare for Saturdays project build.
On Saturday October 10, 2020, Students meet at the shop, the Students worked on the Rover (Drivetrain and Braking System).
On Saturday November 14, 2020, all students meet at Hornets' Nest BMX track, the Students tested the Rover, as well as testing themselves for the competition.

On Thursday December 3, 2020, all students had a Zoom call to discuss repairs made from testing as well as testing results.

Phase 4 Final Scope

The Final scope is Reporting. The report was written by Hannah White.
On Thursday, January 7, 2021, all students meet on a Zoom call to prepare for Saturdays DRR Report wrap up.
On Saturday January 9, 2020, Students meet to wrap up DRR Report.
We are currently on track and guidelines are being met.