Design and Development of a Human Powered Vehicle

Operation Manual

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Abstract

The NASA Human Exploration Rover Competition took place on March 30, 2017. This competition requires two passengers to navigate an extraterrestrial like terrain in the fastest time possible. Team 17 decided to take on the design of the chassis at the beginning of the Fall 2016 semester, and then move forward to accomplish design in brakes, drivetrain, joints, hubs, suspension and frame in the Spring of 2017. Overall, the rover was completed in time for the competition but sufficient time for testing was not available to the team and this lead to the majority of the problems experienced at the competition.

Acknowledgements

Team 17 would like to thank everyone who has helped them to this point. Thank you to the local bike shops: University Cycles, Great Bicycle Shop, and Joe's Bike Shop for parts and advice. Thank you to the student machine shop for information on designing for manufacturing. Thank you to FAMU-FSU SAE club for advice on vehicular design. Thank you to team 17's faculty instructors Dr. Chiang Shih, Dr. Nikhil Gupta and Mr. Keith Larson for their advice on design and project management. And lastly, a special thanks to the Florida Space Grant Consortium for funding this project.

Introduction

The annual NASA Human Exploration Rover Challenge was started in 1993 under the name of the NASA 'Moon buggy' Challenge. The regional collegiate challenge was designed to encourage the development of vehicles and technologies that are up to the task of exploring harsh environments in a similar fashion to the roving vehicles on the NASA Apollo lunar missions. The challenges intent was to foster interest and creativity in young minds interested in further exploration of the universe. Just like the lunar roving vehicle, the competition rovers must abide by specific constraints such as: collapsed vehicle dimensions for storage, and making a vehicle that accommodates two drivers. The main objective of the challenge consists of a time trial around an obstacle course on the grounds of the Marshall Space Flight Center shown in figure 1.

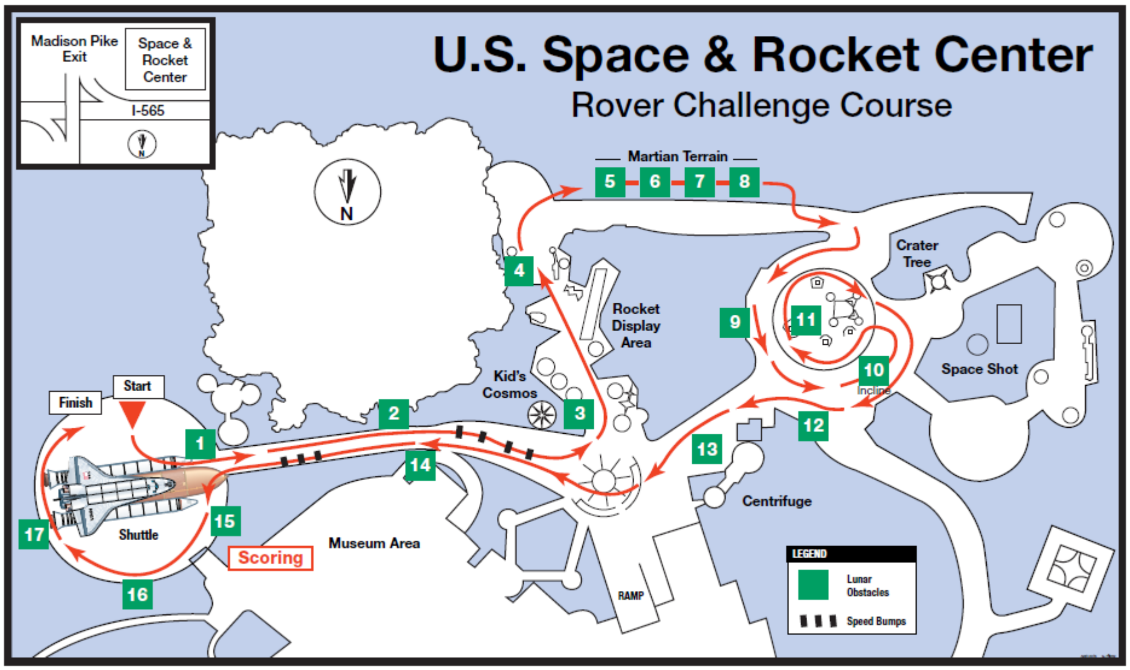


Figure 1: Map of the Course [6]

The course specifics vary by year but are consistent in that they are designed to simulate the terrain of barren planets. The challenge includes optional secondary awards given out for innovations in design, weight, and creativity and so on. The upcoming 2017 challenge features the objectives given by table 1.

Table 1: Available Awards [6]

Awards	Reward ($ amounts)	Details
AIAA Report	250	<12 Page Report Detailing Design
Alternative Drivetrain	500	Vehicle Utilizes drivetrain other than typical chain-sprocket system
Featherweight	none	Lightest Vehicle
Rookie Award	none	Team that posts the fastest 'first year' time, ranked against other first time competing schools
Safety Award	none	Report Detailing measures undertaken to ensure safety before and during competition
Fastest time	none	Post the fastest trial time through the obstacle course

1. Constraints

The following design and competition constraints relevant to FSU's 2017 entry are given by table 2 below. Failure to adhere to any constraint may result in disqualification or a time penalty to the team's trial score.

Table 2: Constraints [6]

Requirement	Description
Occupancy	Vehicle Must carry 1 male and 1 female
Propulsion	Vehicle must not have energy storage devices
Wheel Design	Wheels cannot have any commerical wheel parts except bearings and hubs
Performance	The rover is expected to traverse hills up to 5 ft high at a 30 degree incline
Collapsed Dimensions	Rover must fit within a 5 foot cube in its collapsed form and assembly is apart of the time trial
Weight	The rover must be able to be carried 20 ft by the two riders
Assembled Dimensions	The rover must be no more than 5 ft wide and make at least a 15ft turning radius
Ground Clearance	Any parts in contact with the rider must be greater than 15" from the ground
Occupant Restraints	Seatbelts must be worn by the riders during the race, rovers can be disqualifiedby judges at anytime if they deem a rover unsafe
Flag Display	The US flag and warning stickers must be displayed
Sharp Edges	Sharp edges or protrusions must be covered by padding or dealt with
Fenders	Minimum area of 120 sq.in per fender

2. Needs Statement

The objective of this project is to design, assemble, and drive a vehicle through the 2017 NASA Rover challenge obstacle course in Huntsville, Alabama. The intent is to compete against other vehicles from other institutions in a time trial event. Previous years vehicles will be assessed to determine their weaknesses and strengths in completing the course in order to develop a better vehicle. The main areas of focus will be: structure, weight, power delivery, wheel design, and it must have collapsible configuration.
"There needs to be a ground vehicle that will be operated by a fit male and female driver, capable of competing in the NASA Human Exploration Rover challenge."

3. Functional analysis

Project Function

Team 17 was tasked to compete in the NASA Human Exploration Rover Challenge in Huntsville, Alabama, March 30-April 1. This year's competition saw 99 college and high school entries from all over the world. The challenge was to create a human powered rover that would carry one female and one male over a half-mile course of simulated extraterrestrial terrain of craters, boulders, ridges, inclines, crevasses and depressions. NASA challenged teams to focus on designing, constructing and testing technologies for mobility devices to perform in different environments.

The most important challenge constraints are as follows: it must fit unassembled in a 5 foot volume cube, the unassembled rover (Figure (2) must be carried by the drivers to the course starting line, the wheels must be completely designed and fabricated by the teams without the use of pre-existing wheels and there cannot be any power storage devices at all. Teams are tasked to create a rover based on all competition constraints and race through the course. The teams with the shortest total times in assembling their rover and traversing the course along with additional penalties will win. Every team is given two opportunities to run the course.

Figure 2: Un-collapsed Rover

Using the Rhode Island School of Design as a guide to get started on the project, a three wheel tadpole design was selected. Team 17 was able to design and manufacture a prototype to take to the challenge. The team decided to have separate drive trains with a back to back configuration as can be seen in Figure (3) below.

Figure 3: Back to Back Configuration

4. Project/Product specification

Frame

Frame is composed of ASTM 4130 Steel tubing (chromoly), notched and welded together. The Frame consists of a front rectangular box section to house the front drivetrain and suspension. The box members are vertical to make the control arms equal lengths and camber of the wheels parallel. The frame then tapers down into a triangular truss up until about midway on the frame where a plate forms the hinge for the rover's collapsibility. The triangular truss continues its taper down to the rear which forms into a fork for the rear wheel assembly. The overall assembled length of the rover was just over 10 feet by 5 feet (including the wheels and control arms. The frame was the first and most time consuming aspect to fabricate of the assembly. Partially due to the imprecise nature of cutting notches and welding tubing together. To ease this, chromoly steel was chosen over aluminum because of its desirable welding properties and great strength to weight ratio. The top level of the frame was welded first using a 1:1 scale drawing as a template. This enabled accurate (within 1/16") placement of the cross members on the top and laid the foundation for notching and welding the rest of the truss members. A few support members were bent and shifted off to reduce the amount of compound notches necessary. This did not seem to compromise the integrity of the frame, and was overlooked. What was necessary was the overall dimensions of the frames top and front box section. Once the rest of the components were manufactured, acquired, or modified. They were assembled in the following order onto the frame: Frame and Hinge, Front drivetrain, suspension (Figure 4).

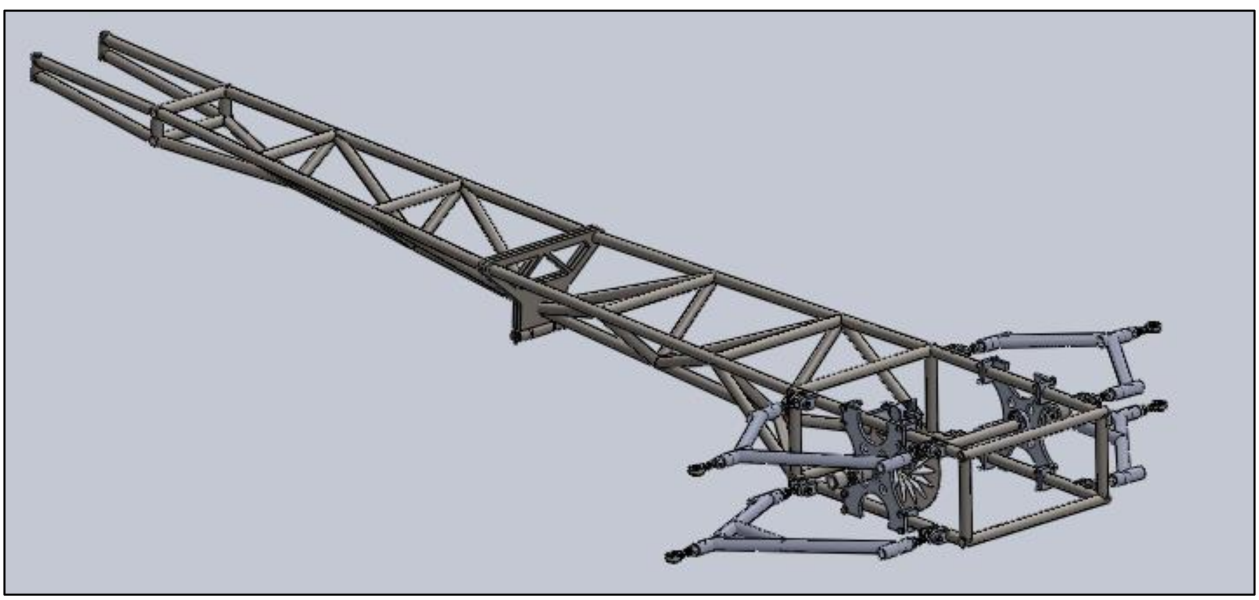


Figure 4: Frame and Front Drive Train Assembly

Front Drivetrain

Two plates with bearings are mounted to the front box section of the frame with U-bolts to allow for forward-aft adjustability. A chromoly steel 3/4” solid shaft makes up the main driveshaft and is consistent throughout the front and rear drivetrains. Mounted to the drive shaft within the box is a 180mm disc brake from a bicycle with an accompanying brake caliper attached by welding tubing mounts directly to the frame. A freewheel cassette with ‘super-low’ 14 tooth sprocket is also mounted to the driveshaft with a modified freewheel adapter hub. Both components are secured with set-screws and 3/16” shaft keys. A bicycle derailleur is mounted with a steel tab to the lower crossbar of the frame and serves the purpose of tensioning the driving chain. A boom to hold the pedal assembly is welded with support members to the top crossbars and includes a custom bottom-bracket from a bicycle building website (special left and right handed pipe threads necessary). The drive shaft is constrained axially with two shaft collars. Two universal joints with an inverted double-D shaft spline make up either continuous velocity (CV) joint attached to either side of the drivetrain. This joint allows power transmission throughout turning, suspension travel and axial travel due to the two previous conditions. Lower universal joints are secured with keys and set screws and the upper joints secured with roll pins. Assembly shown in Figure (5).

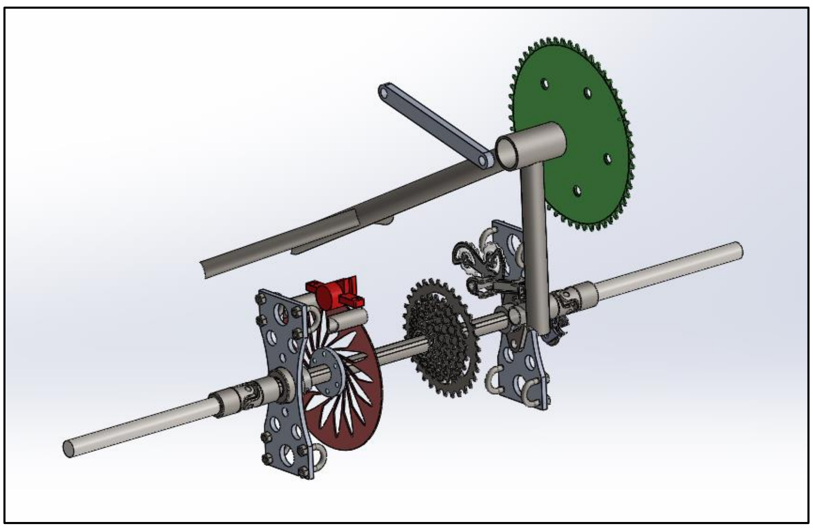


Figure 5: Detailed Front Drive Train View

Suspension

Common double wishbone suspension implemented with 9 3/4” off the shelf shocks attached to the frame and lower arms with tabs. Upper and lower arms are equal length and attached to heim joints and tabs welded to the frame. The arms measured 15.5” wide, extending 11” port and starboard of the frame. Ball joints connecting a water-jetted aluminum ‘live’ spindle and the control arms make up the end of the suspension. The spindles have radial single row bearings pressed into counter bores from either side of the spindle to constrain axial moment within the spindle. Figure (6).

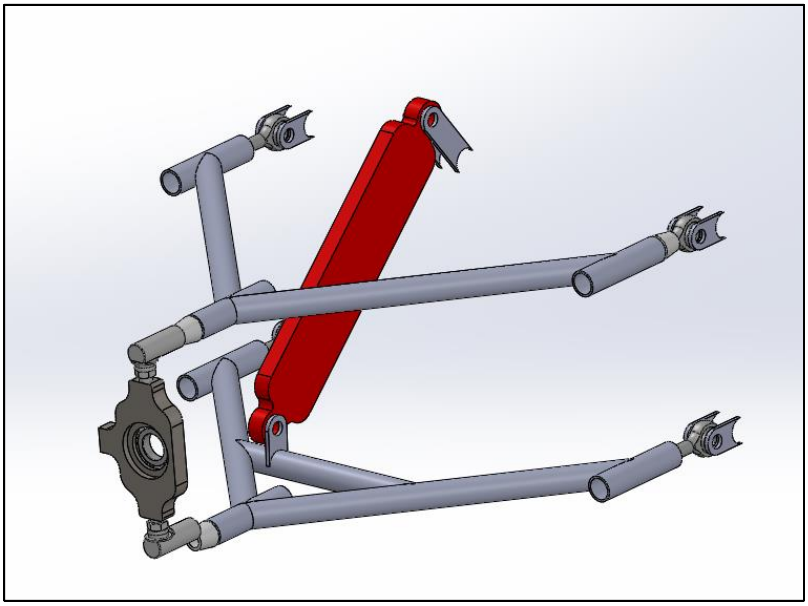


Figure 6: Suspension

Seating

Off the shelf plastic seats attached to an angled (15 degrees front 40 degrees rear) mounting bracket which attaches to perforated rails welded to the frame to allow for forward- aft adjustability. Figure (7).

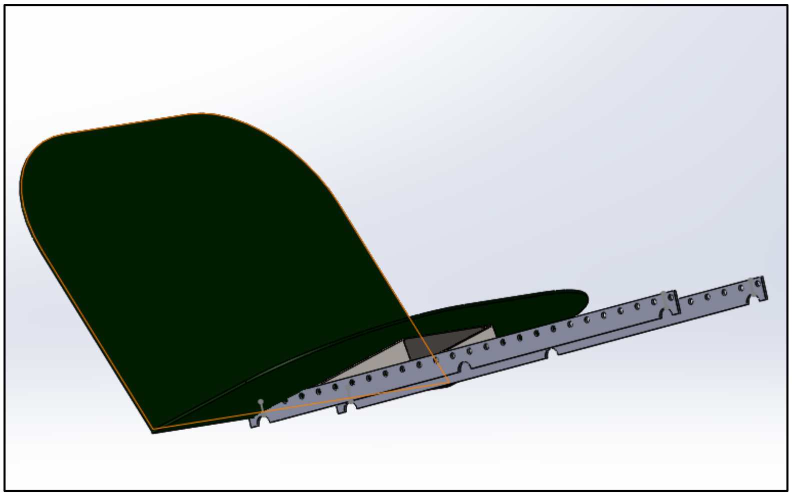


Figure 7: Seat Assembly

Steering

A simplified acumen steering system implemented. Tie rods with attached heim joints connect to a central steering plate that pivots about a vertical member and is actuated by bent handlebars from the opposing side of the plate. The tie rods connect to rods which thread into each spindle and transfer equal motion to each wheel to ensure even steering. Figure (8).

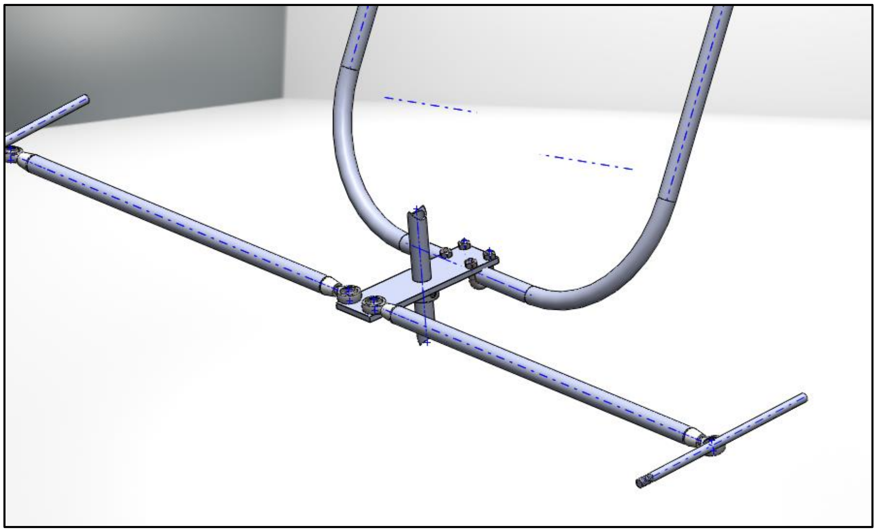


Figure 8: Steering Assembly

Rear Drivetrain

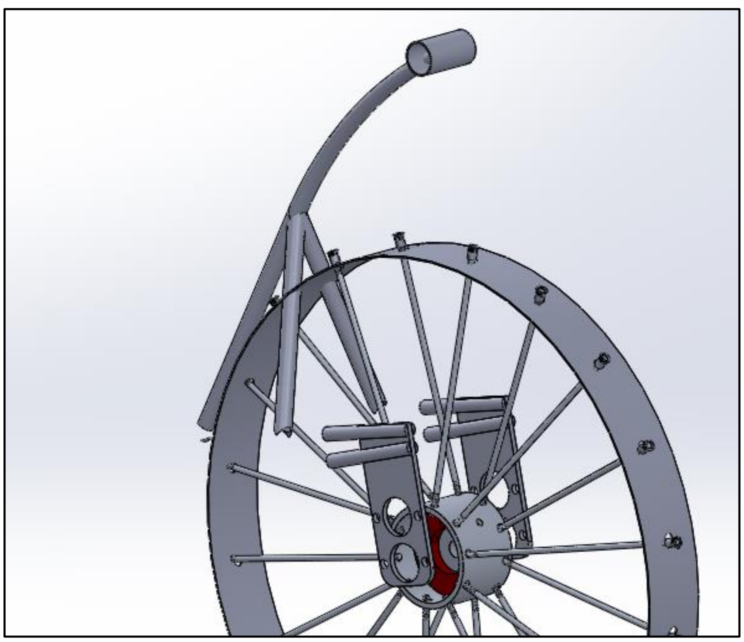
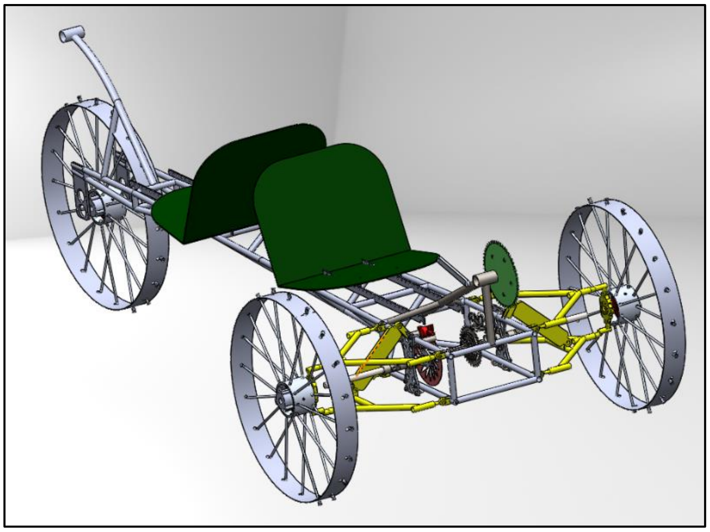


Figure 9: Rear Drive Train

The rear drivetrain consists of a boom welded to the frame that cantilevers over the rear wheel and dropout plates that weld directly to the frame. The plates house bearing mounts similar to the front drivetrain and incorporate the same flange bearings used in the front drivetrain as well. The shaft is secured axially with two shaft collars on the outside of the frames wheel fork and the entire shaft itself is powered. The wheel and wheel hub attach inside the fork to the frame with key and set screws and the same freewheel/freewheel adapter is used in the rear. Figure (9).

5. Product assembly



6. Operation instructions

1. Before operation, ensure all bolts are tightened down and all pins are in place
2. Do a safety check over the entire vehicle to ensure no sharp or dangerous edges are present
3. Adjust seating to each riders most comfortable spot
4. Clasp seat belts and tighten appropriately
5. Begin pedaling and steer in small increments to ensure the vehicle is moving appropriately

7. Troubleshooting

Encountered Problems

On the night before the team packed up to travel to Huntsville, the front left universal joint sheared off. This occurred due to the quality of u-joints that were purchased. The team then rushed to order two higher quality u-joints to ship directly to the hotel. They arrived the morning of the first run. The team rushed to get the new u-joints (Figure 10) retrofitted to fit the shafts since the new joints were almost 2 inches longer than the original. It was extremely beneficial that NASA supplied a “pit crew” that helped work on the rovers and had an entire machine shop set up for the participants to use. When working to put the u-joints on, one of them had a small defect that prevented the key to fit properly in the key way. As a result the team missed their time to participate the first day.

Figure 10: U-Joint

Team 17 was put in touch with a machinist earlier in the semester by Melissa Van Dyk, a NASA engineer who graduated from Florida State University. After reaching out to her she set us up with Barry Martinez and Jim, two NASA mechanical engineers that graciously opened up their homes to us to work on our rover. With the help of Barry and Jim, the new u-joint was fit on to the shaft.

After sitting on it to test again it was soon discovered that the rear boom holding up the drive train for the rear was being bent as it was being pedaled causing the chain to pop off the spindle. In order to fix that, a metal rib was welded on to help stiffen the boom.
The next issue that was tackled was the steering. Originally there was only about 20 degrees of turning which was not nearly enough to make the turns. The simple fix was to extend the turning plate to give more degrees of turning. This proved effective without weight but when weight was added the turning still has glaring issues.

With time running out, the team made their way to the starting line. As the team attempted to pedal to the starting line, the pins that held the higher u-joints sheared at the same time the rear boom bent and hopped the chain off the gears. With no time remaining to fix it the 5 team members pushed the rover around the half mile course to see what else would need to be focused on for next year's team. The wheels all held up fantastically under no weight, and the suspension seemed to maintain well.

Next year's focus should be entirely on the drivetrain. This seemed to be the most common issues that every team ran into. Making a strong drivetrain will then allow for testing of the suspension and wheels.

Regular Maintenance

The main parts of the rover that need to be check are along the drivetrain and wheels. Along the drive train the universal joints need to be checked to ensure they still have grease inside the joint itself. Other factors that may need to be replaced along the drivetrain are the pins that hold the shaft and universal joints together if they are deformed in any way. With the wheels the main upkeep will be to ensure the spokes are properly tightened and equally tensioned around the entire wheel, overtime these tend to come loose. Parts that will need to be replaced if damaged is the tread and the spokes, both are highly susceptible to damage due to the rough terrain of the NASA course.

Spare Parts/Inventory

While ideally the rover will not break at all, it is prudent to bring more parts and material with you when the rover is taken to the NASA competition. At the competition there is a large ‘pit crew’ station with actual engineers and a large amount of equipment that can be used to make nearly any repairs on a team’s rover. With this in mind, these are some spare parts that could be brought to repair the rover: raw material to fabricate new parts, universal joints, wheel spokes, wheel tread, various bolts and matching nut. Also, while the pit crew is there to assist teams, it can be crowded as they are open to all teams. If tools are available to be brought by the team then tool such as these could be useful: drill, vice grip, various wrenches, hammers.

8. Conclusion

With the NASA Rover Competition being the goal of this project, constraints and objectives were easily laid out. Working within these constraints, Team 17 began to work through different ideas to build a vehicle that would make it through the NASA course and hopefully win some awards along the way. When trying to select the correct chassis design, the process was simplified by looking for inspiration from past competition participants and found RISD. This lead to the use of an eight-foot-long frame of a triangular design, made with chromoly. With the base structure decided on we moved into the other major components such as the drivetrain, suspension, rear drivetrain, hubs, and braking. During this process we realized we were low on time and funding so the team began to incorporate any used parts from bicycles that we could get for free. This is how the team got to parts of both our drivetrains and our braking system. The suspension system was modeled after a car’s suspension system with A-arms and a spring. Overall, the rover was completed in time for the competition but sufficient time for testing was not available to the team and this lead to the majority of the problems experienced at the competition.

9. Biography

Garrett Rady

Team Leader

Born and raised in Tallahassee FL, Garrett came to the Florida State University as an exploratory major. Trying such majors as Actuarial Science, Statistics, and Finance he didn't find his true passion until he found Mechanical Engineering. After graduating in May, 2017, with an Engineering degree and a business minor, he plans on using his vast supervisory experience to obtain a project management position in a related field.

Katherine Estrella

Communications/Webmaster

Born in the Dominican Republic and moving to the United States at the age of 12, Katherine is on track to graduate with a Mechanical Engineering degree from the Florida State University in December, 2017. She has research experience in synthesis and characterization of carbon nanotubes. She is currently on track to become a Navy Nuclear Submarine Officer.

Luke Maeder

Lead Mechanical Engineer

Luke is an Eagle Scout from Rockville, MD. His focus in Mechanical Engineering is Sustainability and Power Generation, and has experience in manufacturing and mechatronics. He is applying for the Navy's Officer Candidate School and graduate programs after he graduates with a Mechanical Engineering Degree in May, 2017.

Jacob Van Dusen

Design

Jacob is an Eagle Scout who grew up by the space coast in Cocoa, Florida. He is on track to graduate with a Mechanical Engineering degree in May, 2017. After graduation Jacob is going to enlist into the United States Air Force with a job lined up as a Combat Systems Officer.

Quentin Hardwick

Design

Coming to Florida State University from Tampa, FL, Quentin originally majored in pure mathematics before finding a passion for physics. With this newfound passion, Quentin changed his major to Mechanical Engineering where he is on track to graduate in May, 2017. Quentin's focus is in Dynamics where he can use his love of ODE's and motion equations. After graduation, he plans to make a difference as a civilian contractor for the D.O.D.

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