Utility Terrain Vehicle (UTV)

Senior Design Spring Report submitted to the

Department of Mechanical and Materials Engineering

College of Engineering and Applied Science

University of Cincinnati

in partial fulfillment of the

requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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Table of Contents

1. Problem Statement

There are numerous parts of this vehicle that can be improved, however we are limited on time and resources, so we are going to try to be reasonable with which issues we work on. We aim to address the following issues with the previous UTV project, bolded items are more difficult and require more work:

Redesign Front and Rear Suspension

Improve Steering

Improve Braking System

Improve Fuel Tank Placement and Access

Relocate Ignition Switch

Adjust the Shifter Configuration

2. Research

a. Background of the Problem

This project was a previous project completed by University of Cincinnati students from years prior. Although this UTV is functional, currently there are fundamental issues with the layout and functionality in the braking, steering, and suspension systems. Any modifications will result in adjustments to other existing systems to improve the user experience, i.e. comfort, performance, and ease of use.

The UTV is not expected to be street legal, therefore the impact of this project is limited to the driver and one passenger.

Given that this is an existing vehicle, it will not take long to review the previous drawings and compare those to the UTV. The frame does seem to need serious attention, when compared the drawings the measurements and angles are very different and slopy. Reusing materials to save costs would be ideal, however, to redesign the current configuration we will have to scrap components. Working on a few systems rather than redesigning the entire car is feasible for just the two of us in the time we have available.

The steering is a simple rack and pinion steering assembly. Two major issues to be addressed are the steering wheel position and tuning. The steering wheel is not in a comfortable position to operate the vehicle safely. The toe, or angle of the wheels in relation to the longitudinal axis, is not sufficient for proper steering and ride handling. The current suspension system is a double wishbone with a shock coil configuration. A system like this works well when it is installed properly, in both the front and the rear of this vehicle there were obvious mistakes in welding, orientation, and overall design. The rear wishbones are attached to the frame in completely different ways. There is an apparent positive camber on the tires which is not optimal for tire grip and longevity. The goal is to set it to an acceptable positive or neutral camber, to ensure proper performance. The current type of braking system employed by this vehicle is a disk brake using a hydraulic connection from the pedal slave cylinder to the caliper brake cylinder. The current brake pedal needs to be relocated and properly adjusted to provide adequate control of the vehicle while applying the brake to reduce the vehicles speed.

The placement of the ignition switch is essentially under the drivers' leg, which makes it impossible to start the vehicle without moving your legs in an uncomfortable and impractical way. The current condition of the vehicle brings up several safety concerns related to the placement and quality of some of the individual components. The placement of the battery in relation to the fuel reservoir allow for a possibility of accidental ignition of the fuel reservoir in the case of an accident, double so because the fuel tank is currently improperly secured to the vehicle frame allowing for major shifts in the tanks positioning during operation of the vehicle. The vehicle uses a manual Continually Variable Transmission (CVT) but the current shifting lever either lacks the appropriate leverage or configuration to allow the CVT to be operated by the driver.

b. Applicable Standards

The overarching standard for ATV's is the ANSI/SVIA 1-2023. (1)

Relevant Sections

- 4.1/4.2 – Related to the setup and operation of the brakes
- 4.5/4.6 – Related to the operation and setup of the Clutch/ Gear Shifter
- 4.7 – Related to the Throttle control and design
- 4.13 – The requirement to add a flagpole mounting bracket to the vehicle

Fuel Tanks for ATV's are held to SAE J288 fuel tank standards (Referenced in ANSI/SVIA 1-2023) (2)

Relevant Sections

- 13.8 Fuel Tank Protective Envelope Analysis

Multipurpose Off-Highway Utility Vehicles are held to ANSI/OPEI B71.9-2022 (3)

Relevant Sections

- Controlled by pedals and a steering wheel
- Intended to transport people and cargo
- Minimum carrying capacity of 350 lbs.

c. State of the Art

John Deere TX 4x2 (4)

Figure 1.1 John Deere TX 4X2

The John Deere Gator line of UTVs is one of the state-of-the-art vehicles in the market we are competing to be a part of. The TX 4x2 gator fills a similar market we plan to target with a cargo carrying capacity of 272 lbs. an engine power of 15.5 hp. The Vehicle has independent spring over shock, single A arm suspension in the front and semi-independent coil over shock systems in the rear. It has all wheel hydraulic disc brakes and a weight of 1105 lbs. and a ground clearance of 5.7 inches. The Gator also has a Continuously variable transmission (CVT).

2025 Polaris Ranger SP 750 (5)

Figure 1.2 Polaris Ranger SP 750

The Polaris Ranger SP 750 is Polaris offering in a similar market to the UTV that we intend to produce. The Ranger SP 750 produces 44 horsepower and has a 500 lbs. gas-assisted dump box that has roughly a 2x2 ft bed and a drop gate at the rear. Polaris is also a two-seater with two bucket seats. The front has 9” of suspension travel while the rear has 10” and the UTV comes standard with 11” of ground clearance. The cart has 4-wheel hydraulic brakes and a lock in place transmission for a parking brake with an automatic transmission. The front suspension is a set of MacPherson Struts, and the rear suspension is Dual A-Arms.

<u>CFMoto 2025 UForce 600</u> (6)

Figure 1.3 CFMoto 2025 UForce 600

The CFMOTO UFORCE 600 is a lower cost offering in a competitive market to our UTV. This UTV offers a 36 hp liquid cooled 4wd power system that produces a max torque of 33lb-ft at 4750 RPM. This vehicle also comes with a automatic transmission and a independent front suspension with 10.5 inches of ground clearance using an A arm independent suspension in the front and A double A arm in the rear. At a length of just under 10ft the UForce 600 comes in with a turning radius of 14.9 ft. The Suspension also provides 7.9 inches of travel at the front end and 8.3 in the rear. The bed behind the cabin provides 600lbs of carrying capacity onboard.

d. End User

The End user of our UTV will be people who need a vehicle that can navigate off-road and carrying a decent load of cargo to or from a location over a moderate distance. The people who will most benefit from our UTV will be those individuals or organizations that need a vehicle that can be used to assist in the maintenance of moderately to large plots of land.

e. Summary of Research

After thoroughly inspecting the vehicle there are so many standards that were not followed or implemented, those standards should drive some of the features implemented in the design. It is also apparent that there was a lack of quality when the vehicle was assembled. This can be seen especially in the welds, the suspension, and the frame in general. This is not to discredit the people who worked on this before, but it is a testament to the attention to quality and detail. The end user would be satisfied that it is a vehicle, however we aim to address concerns of apparent safety and performance issues using the standards above and the engineering skills we have developed over the years here at UC.

f. Customer features

1. Safety
2. Cost
3. Ride Comfort
4. Carrying Capability
5. Handling
6. Acceleration Responsiveness
7. Braking Responsiveness
8. Ergonomics
9. Noise
10. Durability

3. Quality Function Deployment

a. Survey Methodology and Results.

Sites used to gather information: A Google form was sent to various groups on various social media apps including Snapchat and Instagram. Survey questions were divided into two sections; Importance of features and Satisfaction with the state of the art.

		Importance of the feature	Satisfaction with the feature in the current technology
Customer Feature	Responses	Average Rank	Average Rank
Safety	34	8	6
Cost	34	5	5
Ride comfort	34	9	6
Carrying capability	34	5	5
Handling	34	7	7
Acceleration Responsiveness	34	7	5
Braking Responsiveness	34	9	5
Ergonomics	34	5	5
Noise	34	1	5
Durability	34	8	8

Figure 2.1 Customer Survey

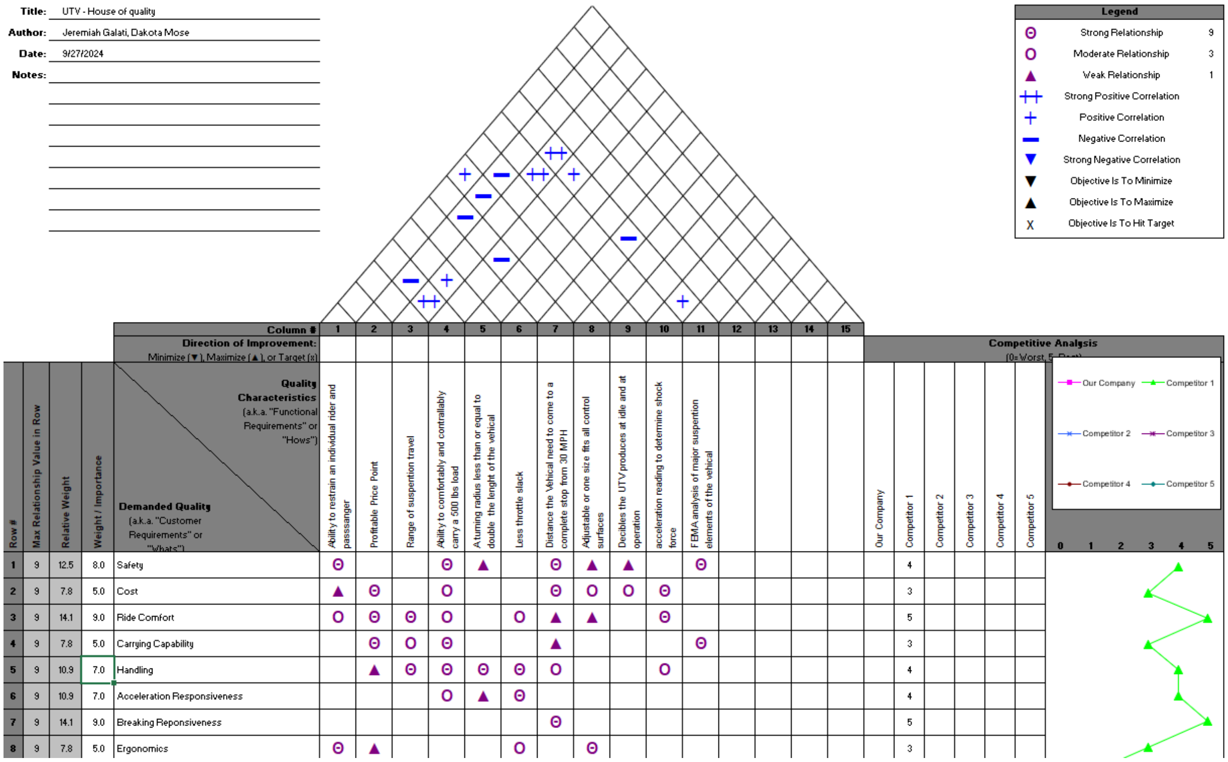


Figure 2.2 House of Quality

b. Engineering Characteristics

- Ability to restrain an individual rider and a passenger
- Profitable price Point
- Suspension Travel
- Ability to comfortably and controllably carry a 500lbs load
- A turning radius is less than or equal to double the length of the vehicle
- Less throttle slack
- Distance the Vehicle needs to come to a full stop from 30 MPH
- Adjustable or one size fits all Controls
- Decibel the UTV produces at idle and at operation speeds

- Take vertical acceleration reading to determine the shock of the vehicle during travel over terrain
- FEMA analysis of the major suspension elements of the vehicle.

c. Product Objectives

1. Braking Response
2. Ride comfort
3. Safety
4. Durability
5. Handling
6. Acceleration Responsiveness
7. Ergonomic
8. Carrying Capacity
9. Cost
10. Noise

4. Design

a. Concept Designs

Based on our customer responses, the most important thing to the design and function of a UTV are the responsive ness of the braking, the ride comfort, and the safety and durability. The majority of advertised UTVs tout these features in the reading material and their media campaigns as selling points to the consumers of their products. The results show that there are areas to improve from the current state of the art UTVs.

Function #1

Our UTV will need to provide a comfortable ride for the driver and passengers of the vehicle.

Function #2

Our UTV will also need to provide a responsive driving experience to allow the driver to have confidence in, and enjoy the features of our UTV.

Function #3

Our UTV will need to be designed to handle the terrain I will encounter in its use a Utilitarian Terrian Vehicle with our consistent failure of parts or the worry that typical use will damage the vehicle.

b. Concepts Drawings

Suspension

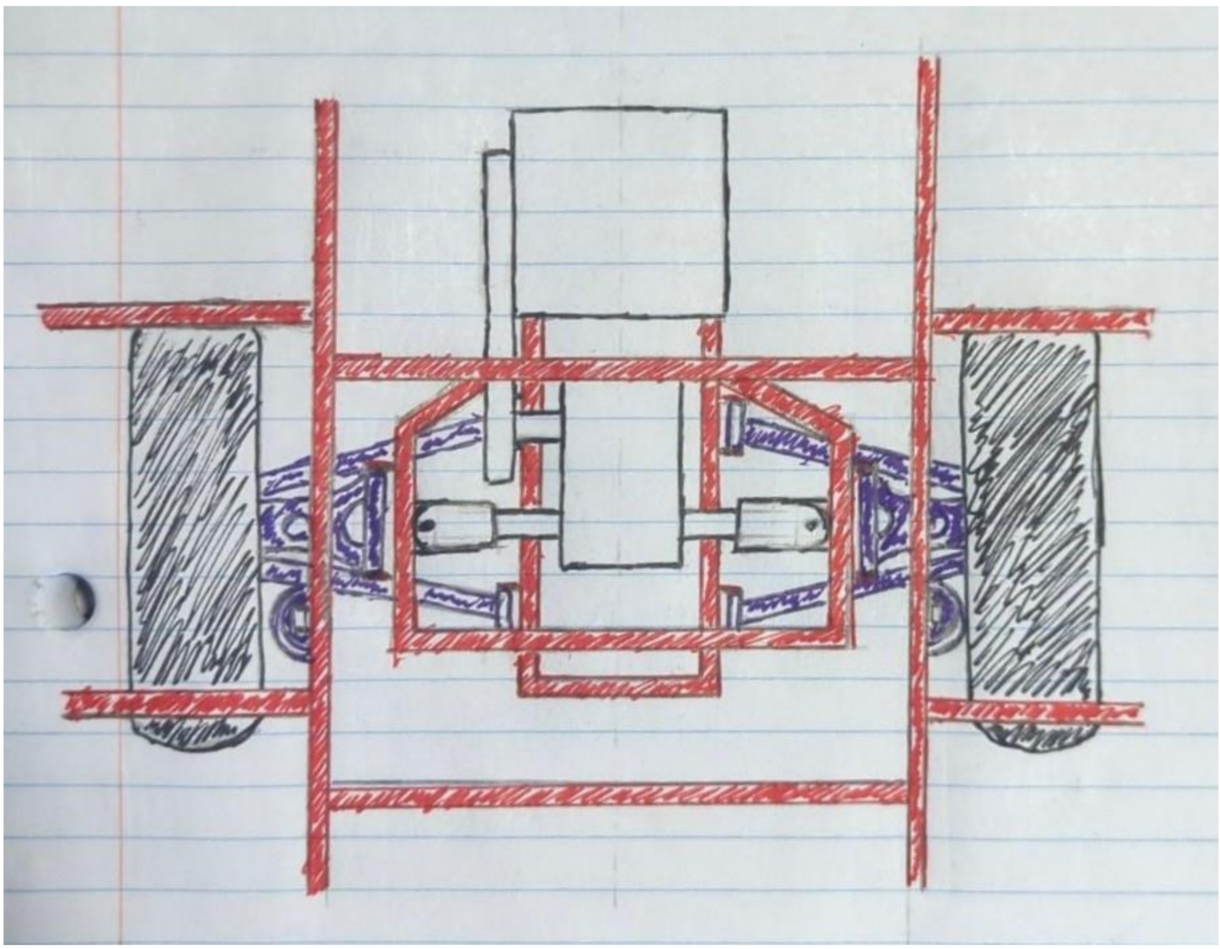


Figure 3.1 The Rear Suspension Concept Drawing

This is a concept drawing of the top view of the rear suspension and engine assembly of our UTV. The previous setup of the rear suspension is asymmetrical due to a shortcoming of the previous designs of the rear suspension. Pursuing this design will improve the position of the wheels throughout the travel of the suspension and allow the wheel to be parallel to each other.

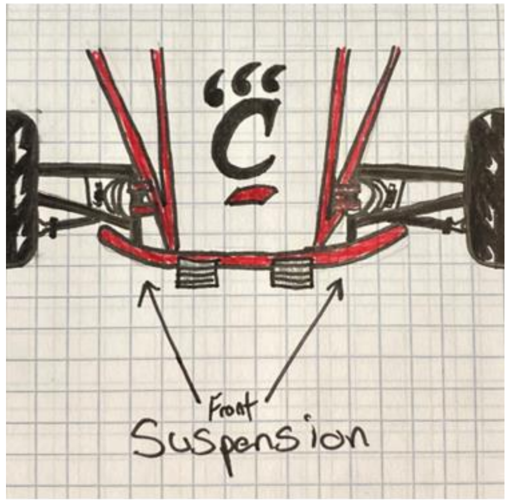


Figure 3.2 Front Suspension Concept Drawing

This concept drawing of the front suspension system is aimed at realigning the wheels. Making the suspension symmetrical will improve ride comfort and handling of the UTV. The previous issue with the suspension in general was the lack of symmetry and camber of the wheels. This design will aim to address those issues.

Braking System

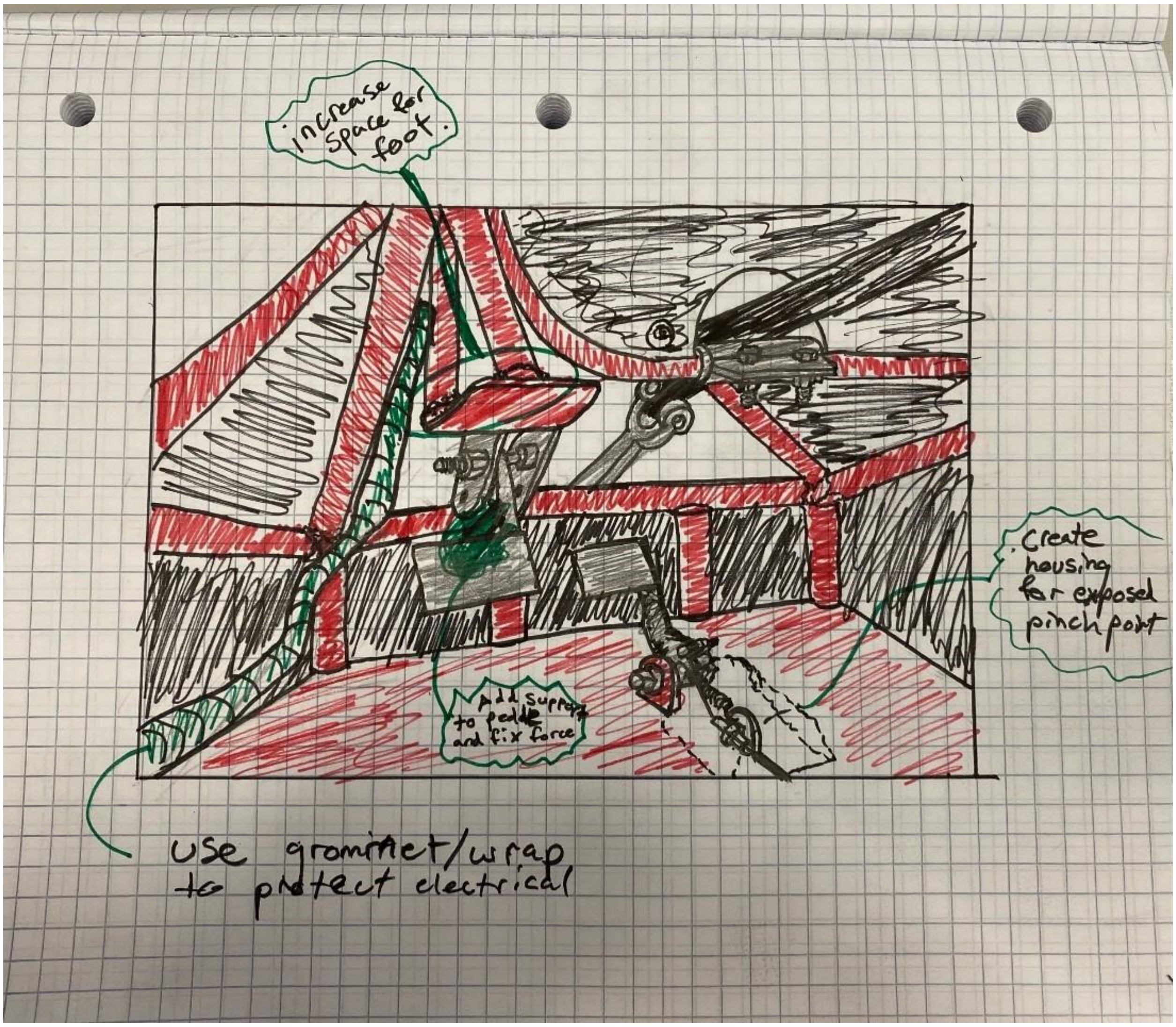


Figure 3.3 Front Components Concept Drawing

The previous configuration of the pedals were not adequate for proper performance in acceleration and brake response. This concept drawing shows how the pedals could be reenforced to avoid the metal from bending due to the large force it currently requires depressing the pedal. There was a guard above the pedals that prevented the driver from hitting their foot on the components above it. The guard was a helpful safety feature however it prevented drivers with big feet from being able to safely use the brake pedal. Safety guarding is important, but the accelerator pedal was exposed pinch points. Overall, there were wires that were loose through the entire cabin that could be damaged easily thus causing safety and durability issues.

c. 3D Models

Suspension

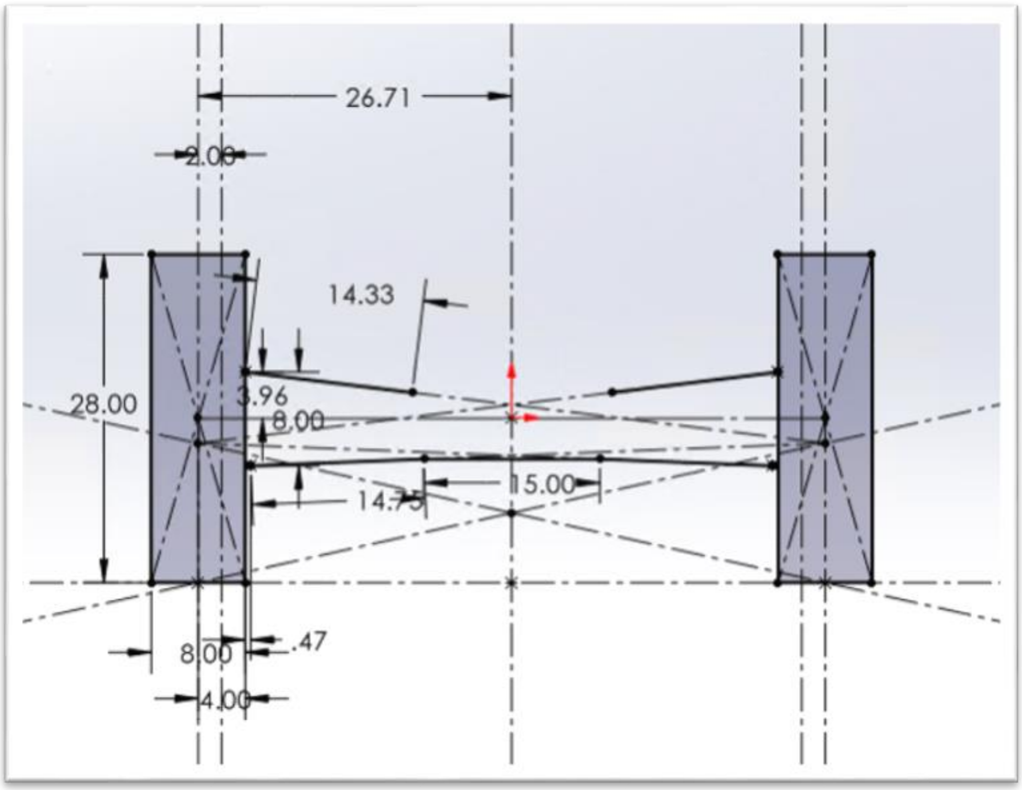


Figure 3.4 Suspension Design

This model was created in SolidWorks using the Instant Center and Roll Height method for suspension geometry. (Race Car Dynamics, William F. Milliken and Douglas L. Milliken) This method is described in the Analysis portion of this paper.

Steering

Figure 3.5 Steering Design

The modeling process for this steering system was relatively simple. Improvements to the previous design are as follows, more secure bracket for rack and pinion, reduced length of steering column, and reduction in steering wheel diameter.

Braking System

Figure 3.6 Braking System

A complete redesign of the braking system was necessary, this will be discussed in the next section. This assembly is constructed of a pedal connected to braking piston fastened to a general frame. This geometry will spatially work well in the vehicle as there is limited space near the drivers' feet.

Fuel Tank

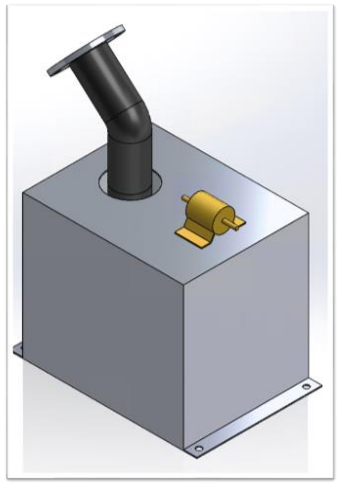


Figure 3.7 Fuel Tank Design

This gas can configuration is an improvement from the previous design, this will be described in the following section. A metal case will cover the gas reservoir to address concerns of having a container exposed to the elements. A gas fill area would improve the functionality of this gas canister, so we added one that would be able to fit the standard gas nozzle from a gas station. The current design is gravity fed into the system which isn't desired in this application since the intended terrain included some off-roading.

d. Design Analysis and Discussion

Suspension

The suspension was designed guided using the instant center and roll height method described in Race Car Dynamics, William F. Milliken and Douglas L. Milliken.

Instant Center and Roll Height Design Method

1. Set tire center to tire center distance

2. Set control arm lengths

3. Set roll center height

4. Scribe a line from the tire center, at the ground, through the roll center height

5. The intersection of the scribe line and the tire center is the instant center.

6. Scribe a line along the control arm through the instant center

The drawing created in SolidWorks is designed in a way that we can adjust the roll center and center to center tire distance as needed. This model shows the geometry for the control arms and will drive any changes to the frame. Using kinematics and dynamics, the linkages were created in 2D to show the travel of the wheel hub, as shown below. The assembly accounted for 2 inches of wheel travel.

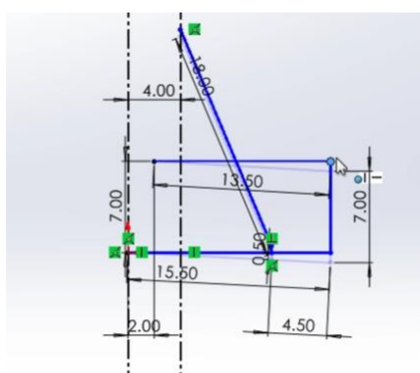


Figure 4.1 Suspension Kinematic and Dynamic Design

This method was found to be inapplicable to our application, do that design was driven by ride height and roll center. First a 3D sketch was created for the frame, tubes were designed to be modular and constrained to the drawing, then models of the transmission, engine, wheels, and axles were introduced to the assembly to show how the model would work in real space. The tubes were designed in a way that when constrained to the frame, the length would match the desired length automatically. We were able to design a ride ride of 13.5 inches that is consistent along the entire vehicle. Below is the final assembly, digital and mechanical.

Figure 4.2 3D Assembly in SolidWorks

Figure 4.3 Working Assembly

Steering

The previous design for the steering was not sufficient, and the system had become loose. The slack in the steering system caused significant issues while static and while being driven. The length of the steering column was too long to be comfortable for drivers. The rack and pinion were welded to the frame rather than the few loose bolts that were holding it in place. Design considerations that were considered were the steering, ergonomics, and space for braking system in the front end of the vehicle. Issues concerning space under the hood became evident when evaluating the current state of the braking system. The brake pedal and master cylinder needed to be replaced, which took up valuable space from the steering. The redesign allows for every component to fit with enough space.

Braking System

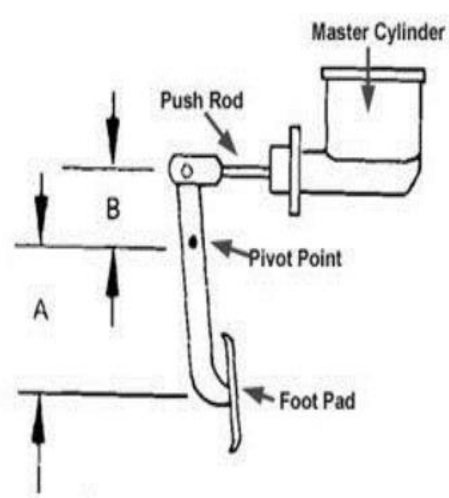


Figure 4.4 Brake Diagram

The brake system was not in good condition as the pedal was too hard to press and in turn the pedal was bent out of shape. The master cylinder was bent and leaked, deeming it unusable. The new design allowed for the input force to be 100 lbf, typical for vehicles. This design allows for both pedals to be depressed naturally with ease.

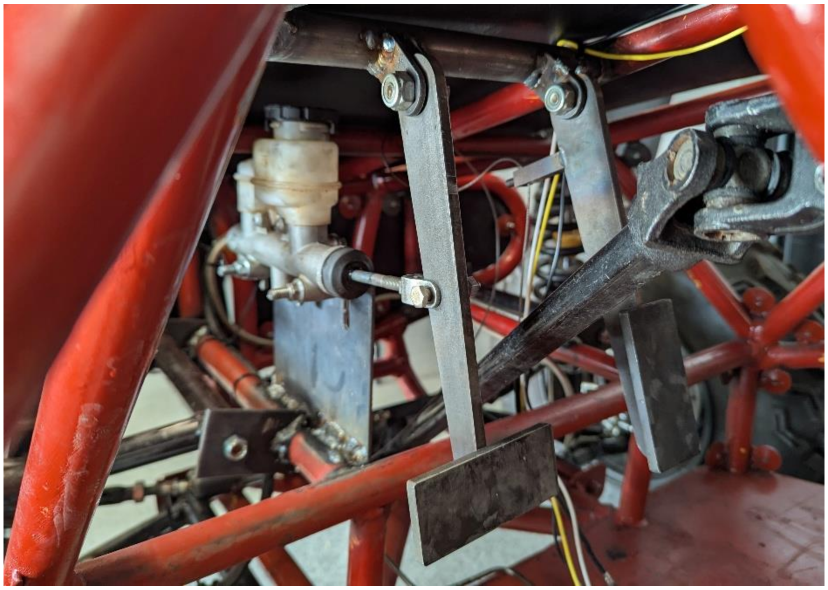


Figure 4.5 Brake Implementation

Fuel Tank

The fuel tank was not in an optimal spot, nor was the method of fuel delivery into the system. previously the plastic fuel tank was zip tied to a shelf above the motor and next to the battery. There is no good way to access the fuel tank with a pump to refuel the vehicle. With safety being a priority, securing the fuel tank is important. Encasing the tank in metal and adding a inlet that is accessible from the outside of the vehicle is the strategy to improve the ergonomics. The functionality improvement will come from adding a fuel pump into the system rather than using a gravity fed method. The implemented method secures the tank in place with bolts and a shelf, fed with the motors' fuel pump.

Ignition Switch

The ignition switch was previously on the floor of the vehicle, to the left of the driver's thigh. This is not ergonomic or functional design as you have to use both hands to get the vehicle to start. The ignition was then moved into the dashboard for ease of use.

Shifter Configuration

To go from drive to reverse there is a shifter in the center of the vehicle. If a passenger is in the vehicle, you would have to ask them to move their leg so you could start the vehicle. This is not okay by our standards for ride comfort and ergonomic design. The functionality is not quite adequate, however the time needed to redesign a shifter system is outside of the capability of two people in the time given. The configuration and ease of use can be addressed and improved by arranging it to fit in the cabin better. This was tricky as we really pushed for the two seater arrangement. Space was limited but the design now allows for comfort and ease of use for the shifter.

5. Fabrication and Assembly

This design project has been at the Victory Parkway campus which has allowed this project to continue to be worked on there. All parts were manufactured with the following tools: Angle grinder, CNC plasma cutter, end mill, horizontal band saw, electric drill, and various hand tools.

The assembly of the vehicle frame was simple on paper but took a lot of manual hours to complete. The angles that the tubes were determined from the solid model that were used to get notching templates. The templates were printed and taped to the pipes to guide the notching process. All tubes were mig welded together.

6. Testing Methods and Results

Three tests were performed on the vehicle; Turn radius, straight line test, and brake response.

The turn radius test was conducted by driving the vehicle at a constant velocity, starting in a straight line then into a circle at the fullest extent of the steering wheel. We found the turn radius to be 20 ft., an acceptable turn radius for navigating a parking lot with ease.

The straight-line test was very straight forward, we drove it in a straight line for as long as it could before deviating from the center. The vehicle maintained a straight line for 30 ft. before veering off significantly. The 30 ft. shows success in steering alignment and the suspension design. Modifications in the suspension could be made to mitigate the significant veering from center.

The final test, brake response, was conducted by driving the vehicle at the top speed then applying the brakes with full force until the vehicle was at a complete stop. We recorded the brake distance to be 7.5 ft. in 3 seconds. The mass of the vehicle was 750 lbsm with a top speed of 20 mph, with these values we were able to calculate the brake force of the vehicle as follows:

$$F = m * a, \quad a = \frac{v}{t}$$

$$F = \frac{m * v}{t} \quad = \quad \frac{750lbm * 20mph}{3sec} = 7335lbf$$

7. Project Management

a. Team Members and Responsibilities:

Dakota Mose – General manufacturing and Structural design focus

– Acceleration and braking systems

Jeremiah Galati – 3D modeling and design calculations focus

- Suspension design

Both teammates will be involved with calculations, 3D design work, and assembly of components. Interior organization will be a collaborative effort to ensure a functional design.

b. Project Budget Limit:

As discussed with our advisor we will be funded from our advisor, with the guidance of "Keep it within reason." Since we are making system redesigns and modifications this project will stay relatively inexpensive, if large expenses come into the project, we are prepared to ask companies to sponsor our project.

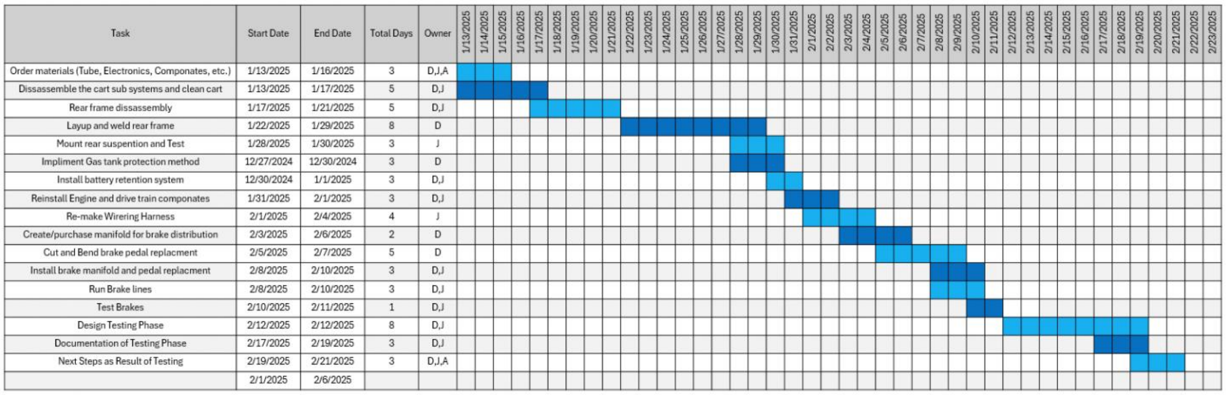
Bill of Material

Item	Quantity	Price	Supplier
1" Steel Tube 6ft	3	227.28	McMaster Carr
Red Wire Spool 100ft (16 ga.)	1	17.29	Grainger
Black wire Spool 100ft (16 ga.)	1	17.29	Grainger
16 ga. Plate Steel (4' x 4')	1	300	Quoted Material
1/2" All Thread (2' Lg)	1	41.82	McMaster Carr
Hydraulic Brake Manifold (6 Port)	1	20.38	McMaster Carr
Fuse Box (11x8x5" Hard Box)	1	26	Amazon
Brake Line (25ft)	1	10.99	Amazon
Brake line nut (15 Piece)	1	11.99	Amazon
Brake Fluid (DOT 3) pint	2	8.48	Lowes
12 V fuel pump	1	9.29	Amazon
8mm fuel tube (10ft)	1	11.98	Amazon
Total		702.79	

c. Key Milestones

Senior Design Exhibition: April 2024

This Gantt chart details the plan to complete, test, and readjust the vehicle in time to be ready for the Senior Design Tech. Expo. In addition to the timing, there is a detailed plan for who is responsible for which tasks and an estimated number of days it will take to complete the task.



Task	Start Date	End Date	Total Days	Owner
Order materials (Tube, Electronics, Componates, etc.)	1/13/2025	1/16/2025	3	D,J,A
Dissassemble the cart sub systems and clean cart	1/13/2025	1/17/2025	5	D,J
Rear frame dissassembly	1/17/2025	1/21/2025	5	D,J
Layup and weld rear frame	1/22/2025	1/29/2025	8	D
Mount rear suspention and Test	1/28/2025	1/30/2025	3	J
Impliment Gas tank protection method	12/27/2024	12/30/2024	3	D
Install battery retention system	12/30/2024	1/1/2025	3	D,J
Reinstall Engine and drive train componates	1/31/2025	2/1/2025	3	D,J
Re-make Wirering Harness	2/1/2025	2/4/2025	4	J
Create/purchase manifold for brake distribution	2/3/2025	2/6/2025	2	D
Cut and Bend brake pedal replacment	2/5/2025	2/7/2025	5	D
Install brake manifold and pedal replacment	2/8/2025	2/10/2025	3	D,J
Run Brake lines	2/8/2025	2/10/2025	3	D,J
Test Brakes	2/10/2025	2/11/2025	1	D,J
Design Testing Phase	2/12/2025	2/12/2025	8	D,J
Documentation of Testing Phase	2/17/2025	2/19/2025	3	D,J
Next Steps as Result of Testing	2/19/2025	2/21/2025	3	D,J,A
	2/1/2025	2/6/2025		

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List of Figures