Utility Terrain Vehicle (UTV)

Senior Design Proposal submitted to the
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by

Dane Oberschmidt

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Thesis Advisor:
Amir Salehpour

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Problem Statement

The Utility Terrain Vehicle solves a simple problem: transportation of people and/or equipment over a large terrain either too harsh or not meant to be travelled by larger vehicles like pickup trucks. There are many different ways to solve this problem; like an ATV, bicycle, or motorcycle even. The advantage of using a UTV comes from the fact that they are larger than these vehicles, and are likely more familiar to operate because they use an ergonomic wheel and pedal system as opposed to handlebar and hand-throttle. Though an ATV also has 4 wheels, the larger size of the UTV also allows for it to be much more stable and increases payload.

Research

Background of the Problem

Utility vehicles have been a crucial advancement in society since we've been able to make them work. From the original 1940 Willy's Jeep to modern Polaris four-wheelers, having the ability to transport people and items across various terrains has proven itself to be an extremely valuable asset (1). In the 1980's, people realized that they were not only useful ways to get around, but they were also toys. Because of their now dual-purpose, prices are on the rise as they the demand is now present for people who just want to use them as playthings. Prices for new 2-seater Polaris start at $11,670 (4). This could very easily be unaffordable for people who could use such a product to reduce the amount of strain on a laborers body. The goal of the UC UTV team is to design and build a UTV that will provide a mechanically simple and cost-effective vehicle that will increase the mobility of laborers, maintenance crews, and other outdoor workers, and cut down on chronic physical strain.

Maintenance crews and other outdoor laborers alike tend to use pieces of equipment that can be too cumbersome or heavy to move long distances. They likewise need a way to bring tools with them so they can repair anything that fails at these sites. Such jobsites easily ask for these laborers to take over 13,000 steps/day, which is 30% more than recommended than the average person (2), and this is neglecting to mention the recommended carrying capacity of a person is 50lbs according to OSHA. Accounting for these specifications, a laborer can easily exceed both of these numbers without a vehicle helping them on larger jobsites.

UTV's by todays standard are very high-tech, rugged, and efficient. Their primary features are a having a 4-wheel drive option and offroad tires for handling tough terrain, a roll cage with a roof to keep its passengers safe, and a bed for handling equipment. Since the goal of the UC UTV is to allow for companies to buy these at good costs and expect good quality, our vehicle does not necessarily need more than the aforementioned equipment. All this vehicle needs is to be dependable, easily repaired, and practical.

This year the team will be focused on the quality of the vehicle. There are aspects of the current vehicle that need some extra help, and I will be leading those projects. I will continue to use off the shelf parts, to ensure that whoever needs to work on this vehicle after us will still do so easily.

Applicable Standards

- Four or more wheels (ANSI/OPEI B71.9-2016)
- Intended to transport persons and cargo (ANSI/OPEI B71.9-2016)
- Non-straddle seat (ANSI/OPEI B71.9-2016)
- Controlled by pedals and steering wheel (ANSI/OPEI B71.9-2016)
- Top speed of at least 25 mph (ANSI/OPEI B71.9-2016)
- Maximum of 80" in overall width (ANSI/OPEI B71.9-2016)
    - Maximum of 4000 lbs. in gross vehicle weight rating (ANSI/OPEI B71.9-2016)
- Minimum cargo capacity of 350 lbs. (ANSI/OPEI B71.9-2016)

State of the Art

The current state of the art is generally seen on farms and in places where work is being done where using a full-sized truck is infeasible. They are also seen in recreational activities, such as dirt racing and general off-roading adventures. Sticking to their functional nature on farms though, they are generally seen carrying items that would wear out the average person if carried too far. An example of this would be carrying items such as weed killer or fuel for tractors that stay in the fields across long distances where trucks either would not fit or would struggle.

Notably, companies like John Deere, Polaris, and Honda all have products that fulfill the needs of the masses. The key specs for the Polaris Ranger 570 are as follows: 44 horsepower, 60" track width, 800lb bed payload capacity, 1500lb tow rating, 16ft turn radius (7). At a cost of brand-new Ranger 570 is $11,670, at the time of writing. In contrast, the UTV that was designed by the University of Cincinnati has only costed roughly $10,000 collectively thus far, and this is including a part that was tested and needed to be swapped because it was not deemed a viable fit. In other words, the UC-UTV is looking to create the most cost-effective yet capable UTV possible.

Transmission wise, the Kawasaki Teryx 1000 uses a Continuously Variable Transmission; a CVT (4). The CVT is a complex transmission, that uses a drive and driven pulley and a belt. The pulleys are tapered, so when more rotation speed is applied, the belt moves along the taper. This decreases the effective gear ratio, despite not using any gears. These transmissions are known to be quite efficient, as they are generally seen in hybrid and economy cars. They are well suited in this application as well, given that the vehicle they are in is not being used to tow very large loads like cars.

In suspension, Bilstein coils and dampers are dominating the offroad market. The system works by using a spring to keep the suspension at a comfortable ride height when not under load (2). In off roading, long and relatively soft springs are used to keep this poise while still being able to climb anything obstacle that may be in the way. The dampers work by having a hydraulic fluid pass through small holes, slowing down the springs tendency to bounce repeatedly. This allows for the vehicle to both stay at and reach suspension equilibrium quickly.

For steering, most UTV's will use a rack and pinion system. This system works by having a gear, a pinion, on the end of the steering shaft that the steering wheel turns. This pinion turns the rack, converting the rotational force into a translational direction. From here, there are control arms connected to the wheels that will pivot, turning the wheels in the desired direction.

End User

The projected end user for this product is people who are working in difficult to reach locations that require more than a few hand tools to do their job. They are generally very durable, easy to work on, and relatively comfortable given their intended usage. With the use of their knobby tires, long-travel suspension, and high payload, they are perfectly suited for this application.

Summary of Work

- Suspension alterations were not able to be made due to time constraints. In order to adjust the front springs to the desired settings, the front control arms would have had to be destroyed due to the limiting constraints in the way the shock was fashioned to them. This would have required going back to the drawing board, per se. In the short amount of time to work on the suspension and all the other aspects that needed adjustment, the vehicle would not have been in working condition by the time it needed to work.
  As for the rear suspension, there was a complication added when a previous team needed to install a new transmission system. The previous transmission had failed due to an inaccuracy in torque specs from the engine to the drivetrain. In short: the previous transmission exploded. The new transmission met the specs that the engine could put out, but was simply too large for the already built frame. In order to fit this larger transmission in, they removed the control arm that blocked it and fabricated a new one. The issue was that this new control arm was not symmetrical to the one on the opposing side, causing an imbalance of force. While driving, the vehicle noticeably leans the rear right wheel to near 45 degrees. It was suggested that the coil could be rotated to help mitigate that kinematic camber, but that would not have fixed the problem.
  - Calculations for suspension:

Spring & Damping

Center of Gravity: x = -115 mm, y = 2224 mm, z = 2103 mm

Mass = 514.5 kg

Coil dimensions: 52mm diameter, 11mm wire, k=502N/m

$$\ddot{y} + \frac{c}{m}\dot{y} + \frac{k}{m}y = 0$$

Critical Damping: C^2 = 4mk = $2 \cdot \sqrt{514kg \cdot 502Nm/mm} = 1015\ Ns/mm$

- The braking system on the vehicle was deemed unsafe under testing from previous teams and Professor Salehpour alike. This did not seem as though it should be the case, as the vehicle had a pad & rotor system all around as opposed to the weaker drum brake system. After checking to make sure no brake fluid was leaking from any of the lines and ensuring that the hydraulic brake system was properly bled, it was deemed that the biggest issue was that the operator could simply not apply enough force to the system. To solve this problem, the brake pedal was examined. It was found that the reason for the poor braking situation was that the fulcrum for the brake pedal was much to far away from where it should have been. Summit Racing, a supplier for a variety of aftermarket automotive performance parts, released a study that concluded that a person “can press on the brake pedal with about 70lbs of force,” while also claiming that an average vehicle requires “800-1200 psi of force at the calipers.” By using the mechanical advantage provided by the brake master cylinder, the brake pedal applies pressure to the hydraulic system which, in turn, amplifies the force input dramatically. In order to increase the applied pressure without requiring that the operator output more than 70 pound of force, a pedal ratio of 9”/3” was designed and installed.

Brake System

$$F = \frac{\frac{1}{2} \cdot m \cdot v^2}{x_{dist}}$$

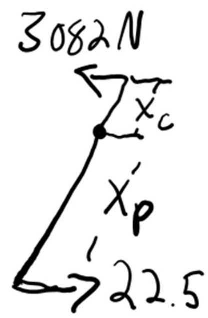
$$F = \frac{0.5 \cdot 515 \cdot \left(\frac{50}{36}\right)^2}{15} = 3082N$$

Pedal force should be ¼ weight of driver, assume 200lbs, 90kg, 22.5 kg desired

Currently, the fulcrum sits 5in away from the end of the pedal and 4 in away from the cylinder

$\frac{F}{3082N} = \frac{4}{5} = 2465N$ is the current braking force required from the driver to completely stop the vehicle, which is far too high

$$\frac{3082}{220} = \frac{14}{1} \frac{xp}{xc}\ length\ ratio$$



- One of the other problems that needed to be addressed was the gas tank constantly sending fuel to the engine without a cut-off switch. In most vehicles this is not a problem, as many use an electronic fuel pump to automatically pump fuel whenever needed (ie turning on and running the engine). This set-up, however, used a gravity fed system. This is not usually a problem, but it requires a cut-off valve so as to not have gas constantly being fed. A cut-off valve was installed in the vehicle to prevent any safety hazards.
- When starting a vehicle, it is common to have the ignition up where the driver can start the vehicle from the driver’s seat. This allows for the driver to safely start and stop the vehicle without needing to walk around and start the vehicle from the engine itself. The UTV formerly had the ignition mounted on the engine, this was moved up to the cockpit, allowing for easy start-stop.
- Similarly to the ignition, it is common to be able to shift the transmission position (Reverse, Neutral, Drive) from the cockpit. There formerly was no mechanism in place to allow for this on the transmission or elsewhere. For easy shifting, a Summit Racing lever & cable were purchased and three mounts were fabricated. The vehicle can now be shifted between it’s three positions from the cockpit.
- In tandem with the suspension issues, the steering system was playing a big part. Firstly, I went through and made sure the car was properly aligned, because the vehicle would noticeably toe in or out depending on any downward or upward force applied to the front, respectively. This did little to help, but it did help. It is common practice for the ball joint of the steering linkage to line up directly with the vertical axis of the control arm’s closest point of the mount to the frame while the car is steered straight forward. To help with this issue, I designed and fabricated two rack and pinion extensions. This helped bump steer as well, but not quite as much as I was hoping. It is also important to make sure one part of the control arms linkages lines up with the tie rod to minimize bump steer.

- Lastly, the engine did not want to fire up when initial testing was done. In order to diagnose the issue, I tried bypassing the fuel filter, bypassing the mechanical fuel pump (bad idea), changing the oil twice, cleaning the carburetor, testing spark plugs & compression. By bypassing the fuel pump, I ended up dumping far too much fuel directly past the carburetor and into the crank case. While attempting to test for compression, I noticed that a large amount of gasoline was coming out despite having the fuel valve closed. After a closer look, I realized that this was causing a massive friction loss in the crank case & causing the engine to run far too rich. After changing the oil for the second time, gasoline and oil came out of the drain plug. I installed a new pump, learning that once a mechanical fuel pump is taken apart it is nearly impossible to get it to work again. Once the carburetor and new fuel pump were installed and the oil was filled to the correct amount, the engine ended up turning over and working.

Quality Function Deployment

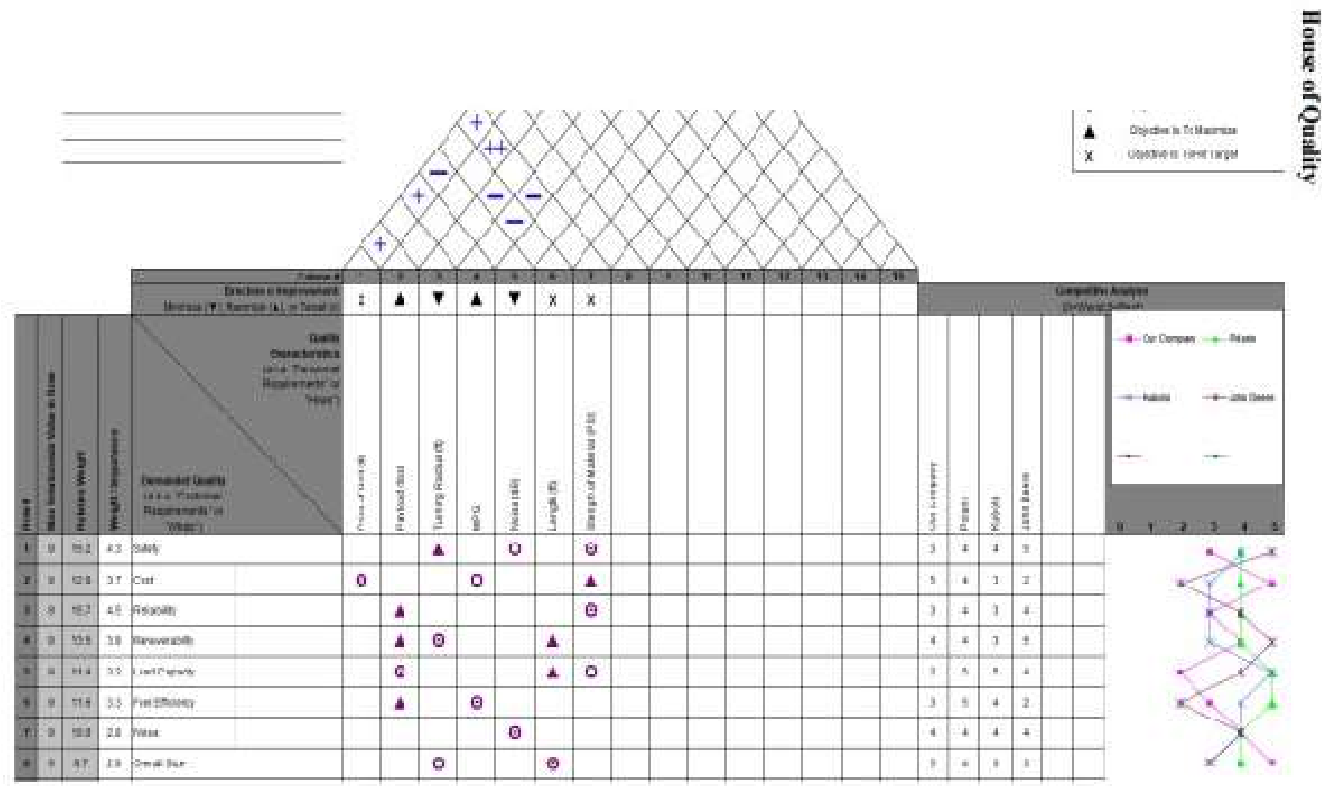
Customer Features

Safety:	Cost:	Reliability:	Durability:	Maneuverability:	Load Capacity:	MPG vs Power:	Noise:	Suspension Dampening:	Braking System:	Turning Radius:	Shifting Gears:
3.94	4.03	4.26	4.61	3.58	2.55	4.48	3.39	4.29	3.81	3.55	3.65

Engineering Characteristics

Safety:	Cost:	Durability:	Size:	Maneuverability:	Load Capacity:	Power vs Fuel Efficiency	Noise:
4.10	4.29	4.10	3.35	2.31	3.61	3.23	2.65

House of Quality



Target or Limit Value															
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	3	6	2	6	3	2									
Max Relationship Value in Column	9	9	9	9	9	9									
Weight / Importance	583.6	526.2	485.5	550.6	442.1	303.5									
Relative Weight	20.2	18.2	16.8	19.0	15.3	10.5									

Product Objectives

Property	Weight	Weight/Score	Action
Safety	12.5	3.9	Use quality materials & parts that are certified for offroad usage
Reliability	13.5	4.3	Use over-engineered materials that will last
Durability	14.6	4.6	Use over-engineered materials that will last
Maneuverable	11.3	3.6	Ensure that suspension & steering can handle tough terrains
Load Capacity	8.1	2.6	Use strong metals and load test for desirable load
MPG	14.2	4.5	Use a relatively small engine, enough to get the vehicle going
Power	1.6	0.5	large engine not required
Noise	10.7	3.4	Encorporate use of mufflers
Suspension	13.6	4.3	Ensure suspension is of a good quality

Concepts Drawings

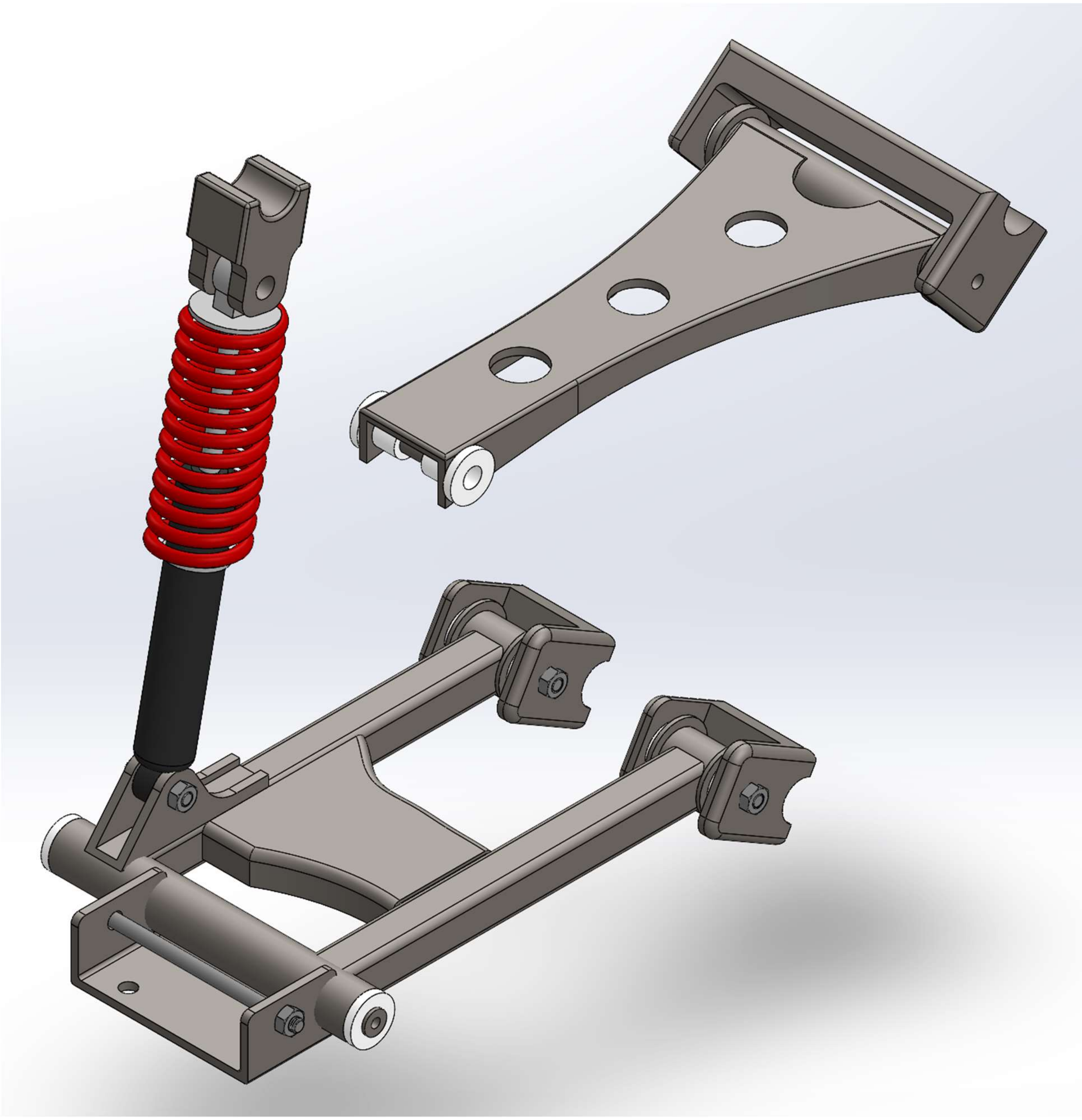


Figure 1: Shock & Control Arms

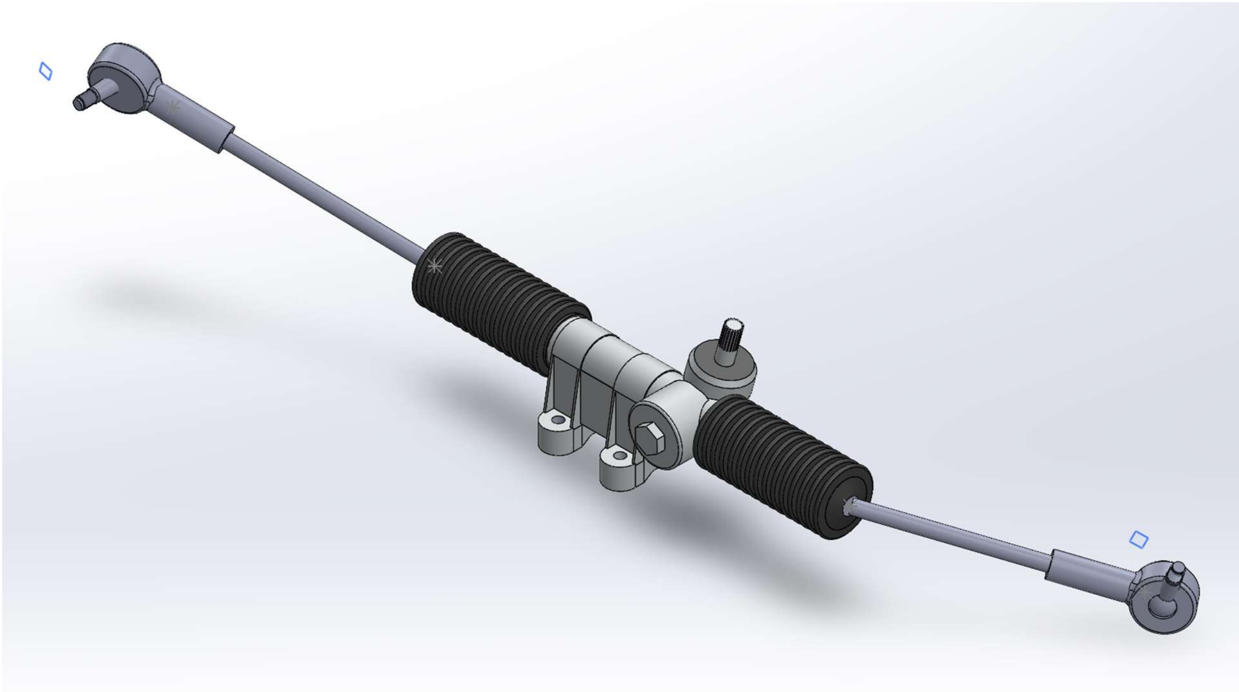


Figure 2: Steering Rack & Pinion Assembly

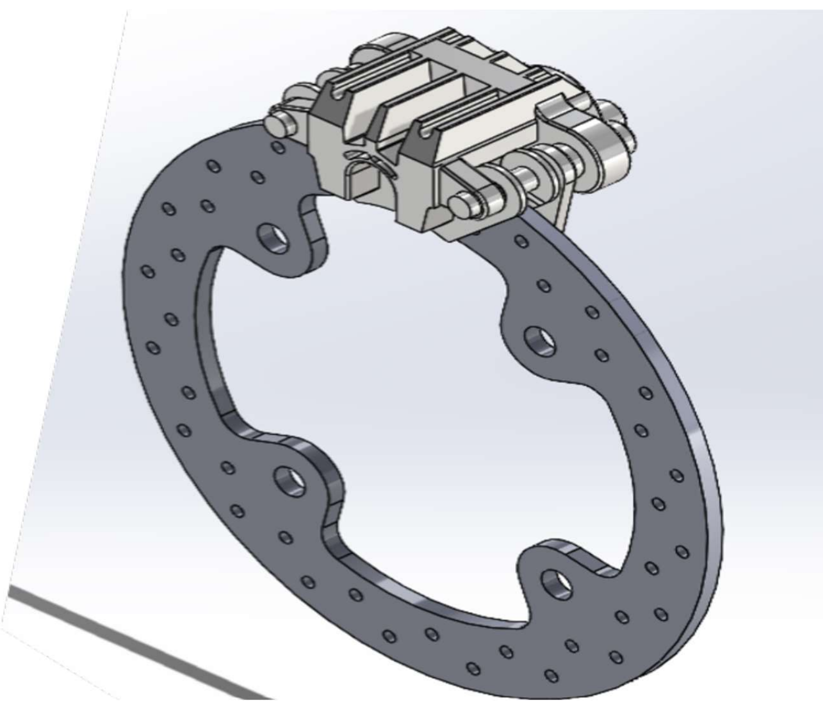


Figure 3: Rotor and Brake Caliper Assembly

Project Management

Project Budget Limit

NOTE: these are all items that may or may not be needed, total budget is subject to change. It is more than likely that this budget is over-estimating what is actually needed to ensure good performance.

System	Part	Needed	Ct	Source	Cost	Total Cost
Suspension	Shock Absorbers	4	2	Amazon	$494.95	$989.90
Front Brakes	Rotors	2	1	Amazon	$104.48	$104.48
	Calipers	2	1	Amazon	$85.00	$85.00
	Pads	4	1	Amazon	$29.48	$29.48
Rear Brakes	Rotors	2	1	Amazon	$104.48	$104.48
	Calipers	2	1	Amazon	$85.00	$85.00
	Pads	4	1	Amazon	$29.48	$29.48
Steering	Rack	1	1	Superatv	$299.95	$299.95
					BUDGET:	$1,727.77

Key Milestones

The primary concern is getting the suspension damping to a point where it is deemed passable. In its current state the car struggles to find suspension equilibrium, this could be fixed by having new shock absorbers installed or by adjusting the current ones. Along with suspension, I would like to ensure that the vehicle is equipped with a durable, yet cost-effective, braking system. This will include new calipers and rotors.

The next item on the list is the steering. The rack currently does not allow for a wide turning radius. I'm hoping to adjust this by either installing a new rack or finding/designing a wide-angle kit for it.

The item is the shift linkage. The car as it stands needs to be shifted into reverse by accessing the gearbox, not by using the shift lever. This could be a simple adjustment or it could require more hardware.

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Appendices