Utility Terrain Vehicle (UTV)

Senior Design Proposal 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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April 2021

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ABSTRACT

The UTV has many different vehicles, however the biggest draw back is the cost. Our project goal was to design a UTV that was cheap and reliable. The group was split into three major areas: Frame, Body panels and brakes, and Suspension and Drivetrain. The group will focus on matching if not beating current designs on the market, making improvements to each category for cost as well as design. As vehicle was not built, the group created process prints for next years group to follow. These drawings will assist in assembly and fabrication. All purchased items were added into an excel list, with part numbers and the websites to allow the next group to find them with ease.

Problem Statement

For our senior design project, we will be completing the design and fabricating a UTV. The aim is to improve upon and/or redesign the current braking system, drive train, and suspension in an affordable, easily adjustable, and maintainable way

Research

Background of the Problem

Many improvements can be made to the modern utility terrain vehicle. We chose to narrow our approach to three main components within the typical UTV: the braking, drive train, and suspension. More specifically, we would like to focus on maintenance and adjustability of each of the three components mentioned above. We aim to make an affordable and simplistic product, perhaps even allowing the operator to adjust "on the fly" without taking their UTV to a mechanic.

Anyone who owns or operates a UTV on a regular basis is impacted by this problem. Mainly, our target audience would be individual users with a more adventurous or on the go lifestyle which might require a quick change or adjustment of suspension or drivetrain parts. In addition, anyone with limited free time who would like to spend it using their UTV instead of taking hours to adjust for different terrain and conditions.

Anybody who has gone for a joyride in any vehicle knows that there is no problem worse than getting ready to go and having to fix an issue with your vehicle. This issue only gets worse when you find the perfect spot to ride your UTV and find out that you need to adjust your suspension for the terrain. This results in a ride back home and a whole lot of disappointment for the user.

Currently, the maintenance options for a UTV come primarily from the manufacturer or aftermarket products which can cost the consumer a pretty penny. The closest quick fixes are very expensive and still require a handful of tools specifically designed for a single purpose (2).

We have identified a few areas where the current solutions are inadequate:

1. Convenience: The ability to adjust the suspension travel and overall height of the chassis relative to the wheels is selectively available, however none of the solutions allow for adjustment without a separate tool. This is one feature which we hope to add to our UTV.
2. Speed: Many current methods of adjustment and maintenance require the consumer to set aside an entire day. We hope to make our maintenance as fast and accessible as possible.

State of the Art

Areas of focus: Frame and Suspension

There are two main types of suspension, independent and dependent. A dependent suspension system is a beam or axle that connects the left wheel to the right, so they work in tandem with each other (6). An independent system runs separate from the other wheel, this is critical to have for trucks or a vehicle going off road. There are three independent suspensions system I will focus on: McPherson strut, double wishbone, and a multi-link system.

The McPherson strut system is most commonly found on front wheel vehicles. This system is among the most cost-effective independent suspension as it uses fewer parts, meaning its simpler and easier to manufacture (6). Due to its simplicity, it does not take up a lot of space, making it an ideal option for smaller and more compact vehicles (6). Since this system is lighter and easy to fix due to a small number of parts, this will be the most effective system for our design.

The next system is a double wishbone style. This system has two wishbone like arms connected to each wheel (6). This system increases negative chamber. So as your vehicle creates body roll when turning, this system will keep your tire perpendicular to the road. This system is used in higher end racing, due to this feature which keeps full grip at higher speeds. This complex system costs more and will increase the weight of the wheel. The benefits from this system are for track driving, which will not benefit our end user.

The last system costs the most of the three and has a very intricate design. The multi-link system utilizes at least three lateral arms and one or more longitudinal arms (6). This system is primary used on luxury vehicles, because this absorbs bumps the best and gives the smoothest ride. Since our end user wants a utility vehicle with off road capabilities, this system will be overkill for what they are wanting in an off-road vehicle.

The frame has two different bracing designs: Front bracing and a rear bracing design.

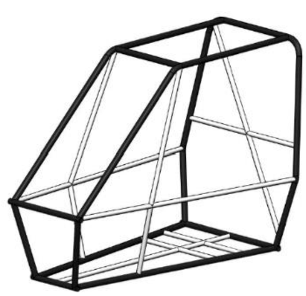


Figure 1

This figure shows the primary members (black) for a front braced frame (7).

The front braced design allows for more customization and space on the rear of the vehicle. This design would allow us to potential add a larger engine, as the whole back of the vehicle can be customized to fit what is needed. Having the weight shifted towards the front of the vehicle offsets the weight of the passengers and the engine, which has a positive impact on the weight ratio. The suspension design will have more freedom to be flexible, as we will not have to work around the frame design. The disadvantage of this setup is reduced visibility for the driver.

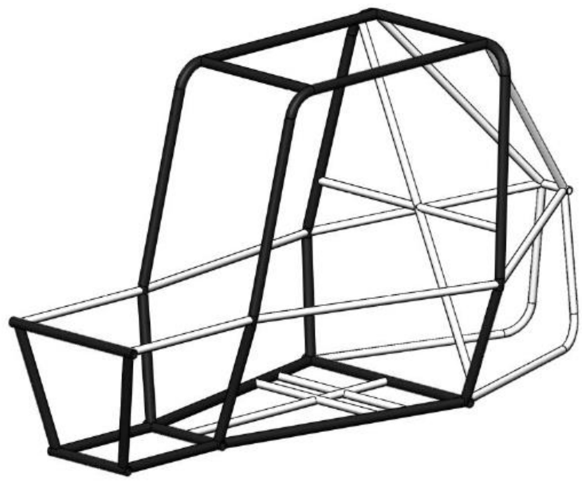


Figure 2

This figure shows the primary members (black) for a rear braced frame (7).

The rear braced design has a structural focus behind the passengers. This design will give the operator the greatest visibility and will allow for a relatively simple firewall design. The disadvantage of this design is center of gravity of the frame will be towards the back of the vehicle. With the weight of the passengers and the engine, this could be a tipping concern if traveling up a steep hill. The engine area will be very limited due to the space required for bracing.

The final area of the frame design will be using steel or aluminum tubing. Aluminum tubing will allow for the lightest frame possible, while still being durable. Cost is a major issue when considering this design choice. Steel tubing is the industry standard because it is cheaper than aluminum, while also being more durable. With cost being a crucial target for our end user, steel tubing would fit best with our design. Aluminum tubing offers no benefit over steel, other than being lighter.

End User

The ideal end user will be 20 to 60 years of age. They will have a medium income. Male or female and able bodied. Some minor mechanical knowledge will be required, but no more than the average individual who changes the oil on their car. The finished product will not accommodate any specific medical disabilities and will be ergonomically suited for a person in the specified age group.

Summary of Research

From my research, I have learned that the McPherson strut suspension system will suit our vehicle and end user the best. This will allow us to deliver the cheapest suspension design to the end user, while still maintaining great off-road capabilities. As for the frame design a steel front braced frame will work well for climbing hills and maintaining the safety of the passengers. Visibility will be slightly reduced for the operator but will be made up through the safety ensuring the center of gravity remains towards the center of the vehicle. A steel frame design will also deliver a cheaper overall cost verses aluminum to the end user.

Quality Function Deployment

Customer Features

Between the 3 people working on this project, a total of 45 people were surveyed. The first survey question asked for the survey taker's perceived mechanical aptitude, allowing us to weigh responses of engineers and mechanics slightly higher. Following this question, they were asked if they had ever owned a UTV. These two questions allowed us to calculate our weighted score. We chose to weigh anyone who rated their mechanical aptitude higher than a 3 as 1.25, while responses below were weighed as 1. The rest of the survey asked the survey taker to rate the importance of customer features. After averaging the answers together and rounding to the nearest decimal, the table below was created

Customer Features	Weighted Score
1.) Maintenance	4.1
2.) Safety	4.3
3.) Braking	3.5
4.) Cargo Capacity	3.7
5.) Transmission	3.6
6.) Steering	3.1
7.) Suspension	3.9
8.) Investment Cost	4.3

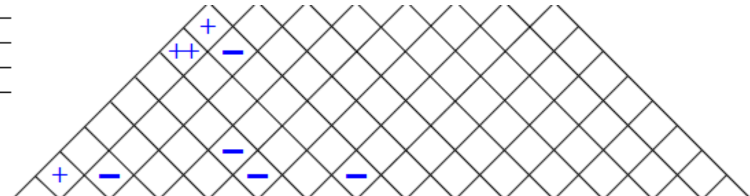
Table 1

Engineering Characteristics

Through further discussion and after a review of our survey responses, the group had to narrow down exactly how to describe the customer features in terms of measurable benchmarks, and units to describe these benchmarks. This led to the following list of engineering characteristics.

1.) Material Strength (psi)
2.) Storage Space (cubic inches)
3.) Suspension Travel (inches)
4.) Brake Clamping Force (psi)
5.) Steering Wheel Turning Torque (ft.lb)
6.) Torque at Wheels (ft.lb)
7.) Life of product (yrs)
8.) Overall Cost ($)

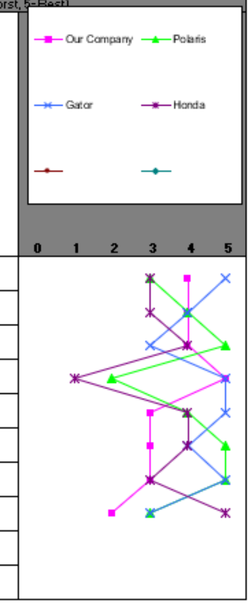
House of Quality



				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	x	▲	▲	x	▼	x	▲	x							
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	**Quality Characteristics** (a.k.a. "Functional Requirements" or "Hows") / **Demanded Quality** (a.k.a. "Customer Requirements" or "Whats")	Material strength (psi)	Storage Space (cubic inches)	Suspension Travel (inches)	Brake Clamping Force (psi)	SteeringWheel Turning Torque (ft.lb)	Torque at Wheels (ft.lb)	Life of Product (yrs)	Overall Cost ($)							
1	9	13.4	4.1	Maintenance	▲						Θ	▲							
2	9	14.1	4.3	Safety	Θ			O	▲		O	O							
3	9	11.5	3.5	Braking				Θ											
4	9	12.1	3.7	Cargo Capacity		Θ	O		▲										
5	9	11.8	3.6	Transmission						Θ		O							
6	9	10.2	3.1	Steering			▲	O	Θ	O									
7	9	12.8	3.9	Suspension	▲	O	Θ		▲	O									
8	9	14.1	4.3	Investment Cost	▲						▲	Θ							
9																			
10																			
				Target or Limit Value	36,000	7	10	680	2	45	8	15,000							
				Difficulty (0=Easy to Accomplish, 10=Extremely	1	2	2	5	4	3	5	8							
				Max Relationship Value in Column	9	9	9	9	9	9	9	9							
				Weight / Importance	167.2	147.5	161.6	176.1	130.5	175.1	177.4	218.0							
				Relative Weight	12.4	10.9	11.9	13.0	9.6	12.9	13.1	16.1							

Competitive Analysis (0=Worst, 5=Best)

Row #	Our Company	Polaris	Gator	Honda		
1	4	3	5	3		
2	4	4	4	3		
3	4	5	3	4		
4	5	2	5	1		
5	3	4	5	4		
6	3	5	4	4		
7	3	5	5	3		
8	2	3	3	5		
9						
10						

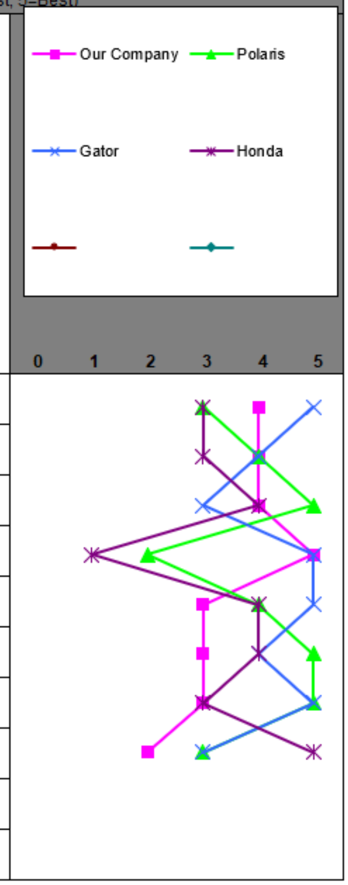


▼ Strong Negative Correlation
▼ Objective Is To Minimize
▲ Objective Is To Maximize
X Objective Is To Hit Target

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Column #	1	2	3	4	5	6	7	8
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	x	▲	▲	x	▼	x	▲	x
				Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / **Demanded Quality** (a.k.a. "Customer Requirements" or "Whats")	Material strength (psi)	Storage Space (cubic inches)	Suspension Travel (inches)	Brake Clamping Force (psi)	SteeringWheel Turning Torque (ft.lb)	Torque at Wheels (ft.lb)	Life of Product (yrs)	Overall Cost ($)
1	9	13.4	4.1	Maintenance	▲						⊙	▲
2	9	14.1	4.3	Safety	⊙			○	▲		○	○
3	9	11.5	3.5	Braking				⊙				
4	9	12.1	3.7	Cargo Capacity		⊙	○		▲			
5	9	11.8	3.6	Transmission						⊙		○
6	9	10.2	3.1	Steering			▲	○	⊙	○		
7	9	12.8	3.9	Suspension	▲	○	⊙		▲	○		
8	9	14.1	4.3	Investment Cost	▲						▲	⊙
9												
10												
				Target or Limit Value	36,000	7	10	680	2	45	8	15,000
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	1	2	2	5	4	3	5	8
				Max Relationship Value in Column	9	9	9	9	9	9	9	9
				Weight / Importance	167.2	147.5	161.6	176.1	130.5	175.1	177.4	218.0
				Relative Weight	12.4	10.9	11.9	13.0	9.6	12.9	13.1	16.1

Competitive Analysis
(0=Worst, 5=Best)

Our Company	Polaris	Gator	Honda		
4	3	5	3		
4	4	4	3		
4	5	3	4		
5	2	5	1		
3	4	5	4		
3	5	4	4		
3	5	5	3		
2	3	3	5		



Product Objectives

Based on our House of Quality the engineering characteristics are listed below in order of importance, with the first on the list being most important

1.) Overall Cost (16.1%)
2.) Life of Product (13.1%)
3.) Brake Clamping Force (13.0%)
4.) Torque at Wheels (12.9%)
5.) Material Strength (12.4%)
6.) Suspension Travel (11.9%)
7.) Storage Space (10.9%)
8.) Steering Wheel Turning Torque (9.6%)

Our group has certainly set some ambitious goals, but there is no doubt in our mind that we will be able to at the very least achieve these goals, with the target being to exceed them in the design of our UTV.

Design

Design Alternatives and Selection

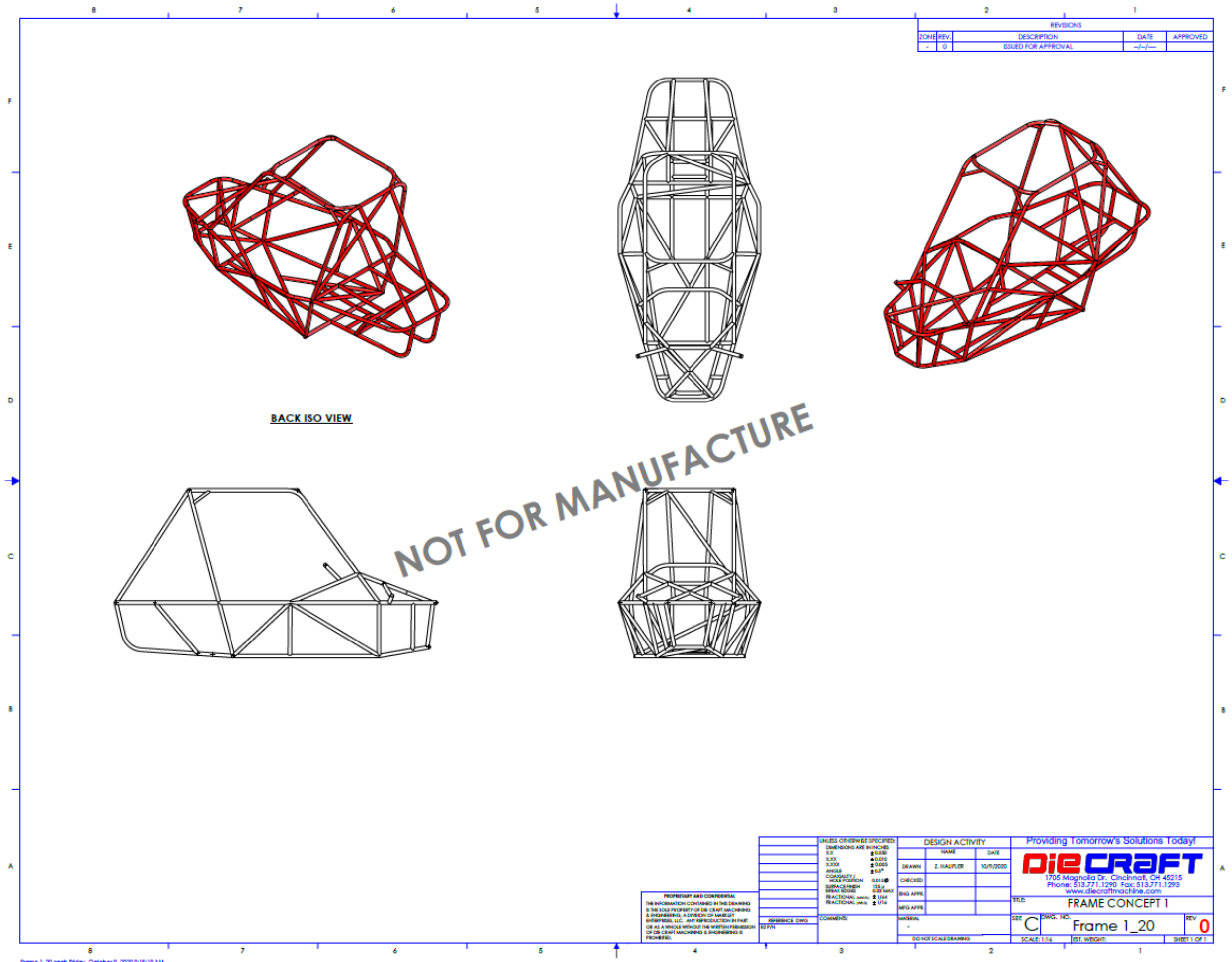


Figure 3

This is a screenshot of my first frame concept design. Looking around on the internet, the common theme I found was all featured a climb in design. This means that there is no door hinge to swing open for easy access to the seats. I replicated that setup to give the frame more overall rigidity. Having this in mind during the design stage, I used a front braced frame design as mentioned in my state of the art. Going this route will allow our group to ensure any components going into the back of the frame would fit. This would allow for more flexibility if our plan doesn't go 100% and would allow us to adapt without modifying the frame a significant amount.

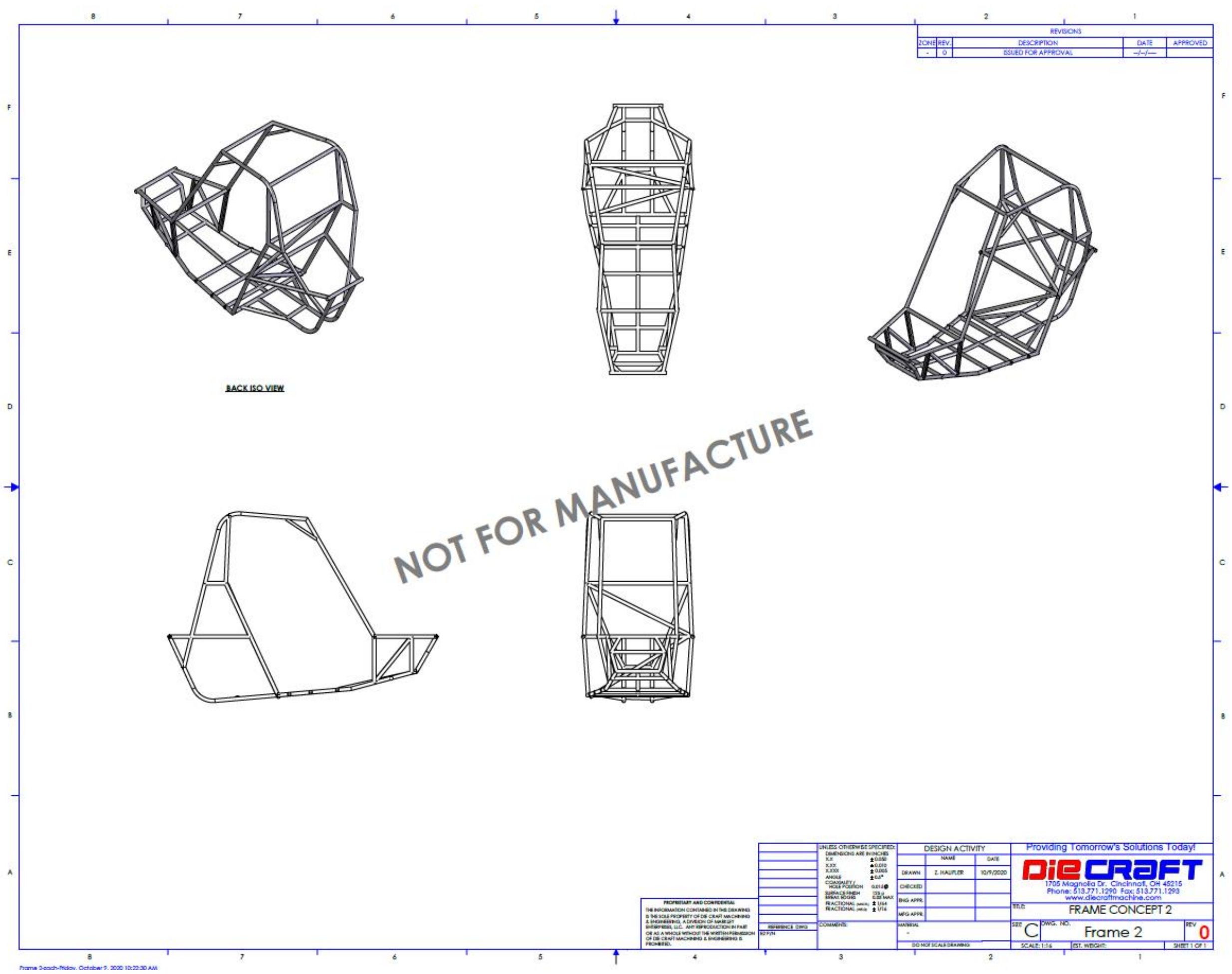


Figure 4

This is my second concept, with a rear support frame design. As you can see compared to the first concept this allows for greater visibility for the driver. This design will also give more space for the driver and passengers legs and give them more room as opposed for a front braced design. I chose to model both braced frame designs to give our group options on what we feel would be the best for our end user. I also added a cutout for a door hinge that will be developed to allow our vehicle to be used by the older age group of our end user. This is not a design I have seen very often when searching for similar utility vehicles. The one drawback of this design concept is we are very limited in the rear of the vehicle. This will take extensive work to hammer out all the details, ensure our products will all work in unison. After the frame is welded up, there is no margin for area because we will not be able to modify the rear design after the weldment is completed.

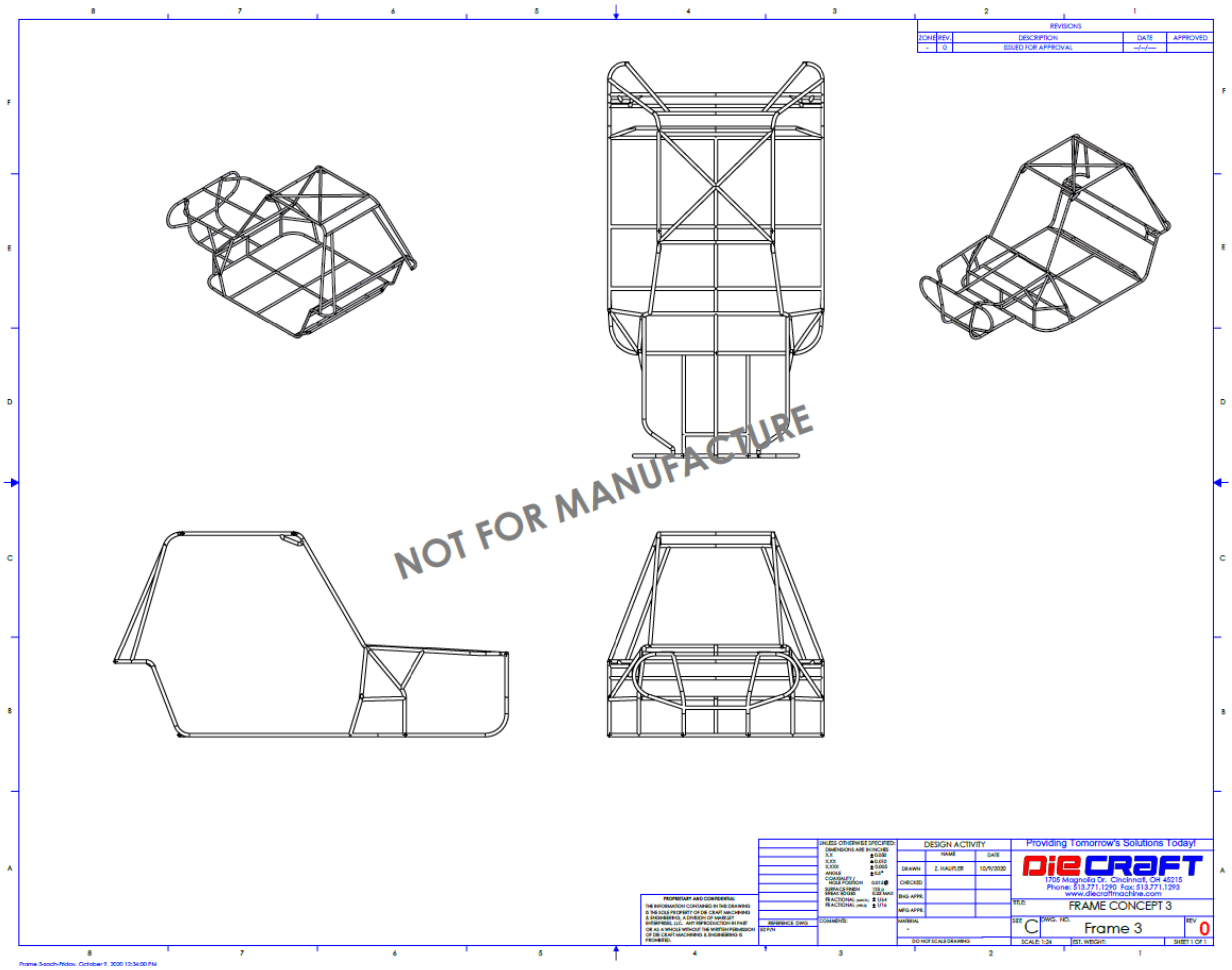


Figure 5

This is the final design concept; this design was based off the frame that was welded from the group last year. We went and looked at the frame, taking pictures and analyzing what is needed to complete this project. This design was constructed off the pictures I took from our meeting. There may be components missing, as we are not allowed back on campus to further the project. Ultimately, we will analyze this concept design with FEA and determine what areas of the frame need reinforcing and if this design will work. This concept is a front braced design, so this allowed the previous group to modify the back components without compromising structural integrity of what was already built. This will give our group a chance to change out components we feel will be a better fit for the vehicle. The design also features a cutout in the frame for a hinged door design. This is a feature no one else on the market has for a vehicle at this price with a tube frame weldment.

Material Selection

The material we are using for our frame modification is 1018. For this we are following the BAJA rule book for material spec's. For a quote, I used A513 which from my co-op experience the price is on par with 1018 tubing. The reason I used this was this was the only material available from a supplier my co-op uses. I chose not contact a supplier to receive a quote based on the uncertainty about the fabrication of our project.

AISI 1018 steel tube technical data

Condition	Nominal Yield Strength psi	Nominal Ultimate Strength psi	Nominal Elongation in 2%	Equivalent Rockwell Hardness	Equivalent Brinell Hardness
GRADE 1018					
c .15/.20 Mn .60/90 P .40 max S .050 max					
Hot-Rolled	35,000	60,000	30	B-68	116
Normalized	38,000	58,000	35	B-66	114
Soft-Annealed	33,000	50,000	40	B-57	97
As-Drawn	70,000	85,000	10	B-87	170
CD-Stress Relief Annealed	60,000	80,000	15	B-85	163

Figure 6

This shows the material properties of the tubing chosen

Application of Code

We will follow the size guidelines, as well as the support member locations. For our frame design, we will use their requirements in our vehicle to ensure we meet the factor of safety requirements.

B.3.2.16 - Roll Cage Materials

The material used for the Primary Roll Cage Members and bracing must meet one of the following requirements:

- Circular steel tubing with an outside diameter of 25 mm (1.0 in) and a wall thickness of 3 mm (0.120 in.) and a carbon content of at least 0.18%.
- A steel shape with bending stiffness and bending strength exceeding that of circular steel tubing with an outside diameter of 25 mm (1.0 in.) and a wall thickness of 3 mm (0.120 in.). The wall thickness must be at least 1.57 mm (0.062 in.) and the carbon content must be at least 0.18%, regardless of material or section size. The bending stiffness and bending strength must be calculated about a neutral axis that gives the minimum values.

B.3.2.3 - Secondary Members

Secondary members must be steel tubes having a minimum wall thickness of 0.89 mm (0.035 in) and a minimum outside diameter of 25.4 mm (1.0 in) or rectangular steel tubes having a minimum wall thickness of 0.89mm (0.035 in) and a minimum outside dimension of 25.4 mm (1.0 in).

Figure 7

This is a screenshot from the BAJA rulebook that we will follow for our frame design.

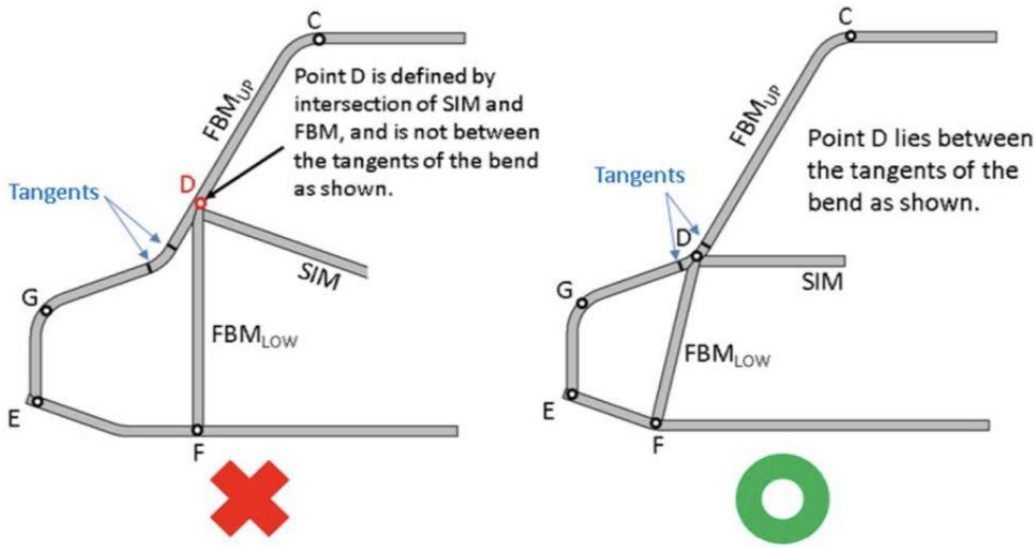


Figure 8

This picture is also from the BAJA rulebook that shows the design of how the front of the vehicle and roll cage should be designed.

Ultimately, we chose to use the existing frame from last year's group. We came to this conclusion by running FEA on the current frame and ensured we would be able to modify the frame to meet a decided factor of safety. We reinforced the front of the frame design, as the factor of safety was below 1. We ran numerous tests to ensure this frame design would be safe for our occupants.

Finite Element Analysis

Front impact collision at 35mph

Calculations

- Mass
    - $\mathrm{m} = (\text{vehicle weight}) + (\text{passanger weight})$
    - $\mathrm{m} = 190\text{lbs} + 500\text{lbs}$

- $m = 690\text{lbs} = 313\text{kg}$

- Force
  - $F = m * a$
  - $F = 313\text{kg} * 6 * 9.81\frac{m}{s^2}$
  - $F = 18{,}423.18\text{N} = 4{,}141.70\text{lb}_f$
- Impulse Time
  - $f_{avg} = m * \frac{\Delta v}{\Delta t}$
  - $\Delta t = m * \frac{\Delta v}{f_{avg}}$
  - $\Delta t = 313\text{kg} * \frac{9.81\frac{m}{s}}{18{,}423.18\text{N}}$
  - $\Delta t = 313\text{kg} * \frac{9.81\frac{m}{s}}{18{,}423.18\text{N}}$
  - $\Delta t = 313\text{kg} * \frac{9.81\frac{m}{s}}{18{,}423.18\text{N}}$
  - $\Delta t = 0.166\text{s}$

Stress

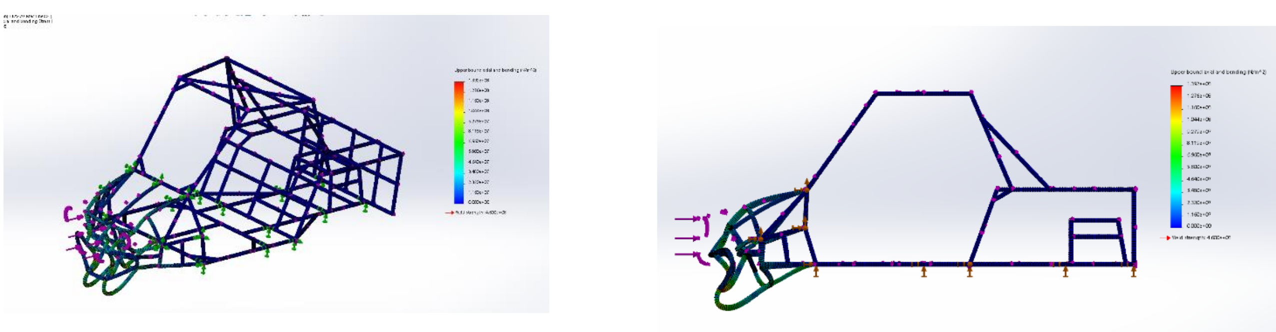


Figure 9

Above are the results for the stress plot

Displacement

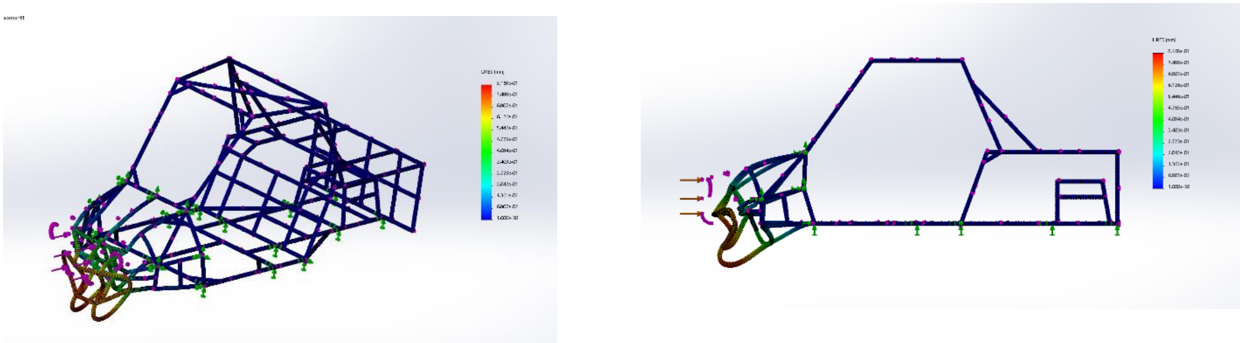


Figure 10

Above are the results for the displacement plot

Factor of Safety

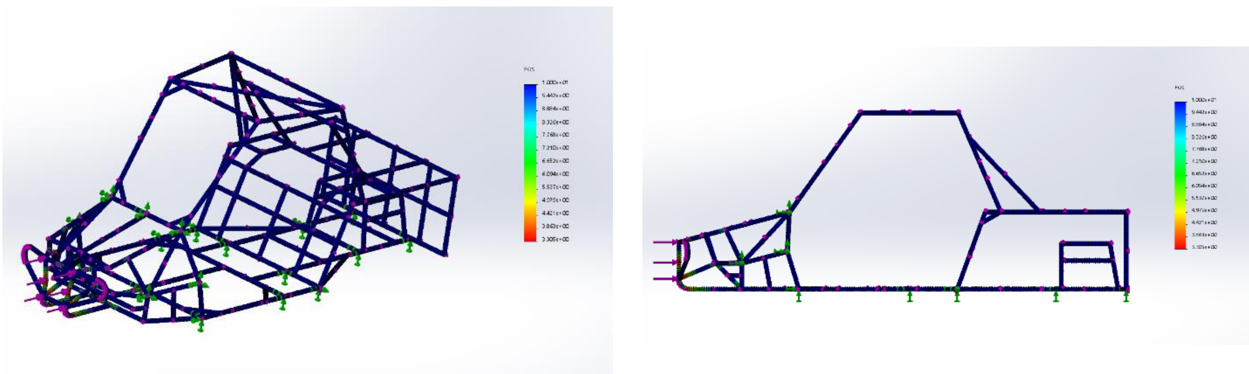


Figure 11

Above are the results for the factor of safety plot

This is a simulation of a front end collision at 35mph. This was done using a G-Load of 10. This is an extreme circumstance, realistically it would be closer to 5. So the factor of safety issues are the lowest scenario. The low factor of safety areas are mainly due to the weldment profiles not being able to compensate for a radius bend. So this created a stress concentration at the miter cut tubes. This will not be an issue in the real world. Also with the G-Load being so high, the factor of safety would jump significantly if a factor of 5 is applied. The reason I ran these at that number is to prove that the design is still above a 1 Factor of Safety and is still deemed as acceptable.

Side impact collision at 35mph

Calculations

The calculations are the same as the front end collision

Stress

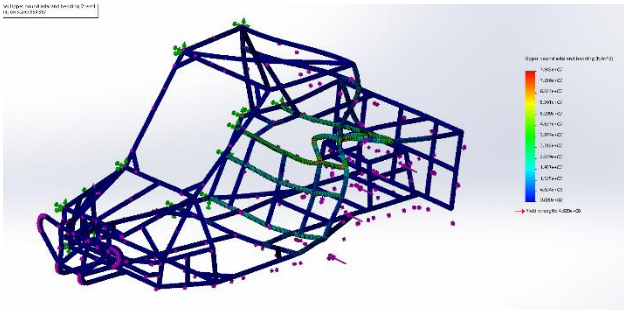


Figure 12

Above are the results for the stress plot

Displacement

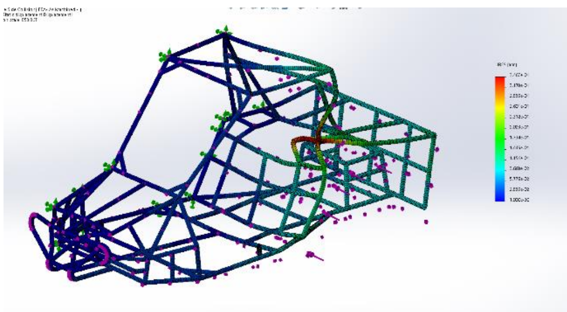


Figure 13

Above are the results for the displacement plot

Factor of Safety

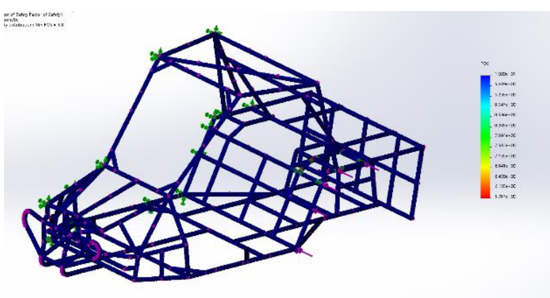


Figure 14

Above are the results for the factor of safety plot

The next impact test done was a side impact simulation. This simulation would be the result of striking a tree with the side of the vehicle. This test preformed the best with the highest factor of safety. This is mostly due to the force being transferred directly to the cross members. This doesn't result in much bending of the tubes. This will be the most likely crash scenario to happen.

Top Impact collision

Calculations

- Force
  - $f_{avg} = m * \frac{\Delta v}{\Delta t}$
  - $f_{avg} = 313\text{kg} * \frac{(9.81\frac{m}{s} - 0)}{0.16\text{s}}$
  - $f_{avg} = 19{,}190.81\text{N} = 4314.26\text{lb}_f$

Stress

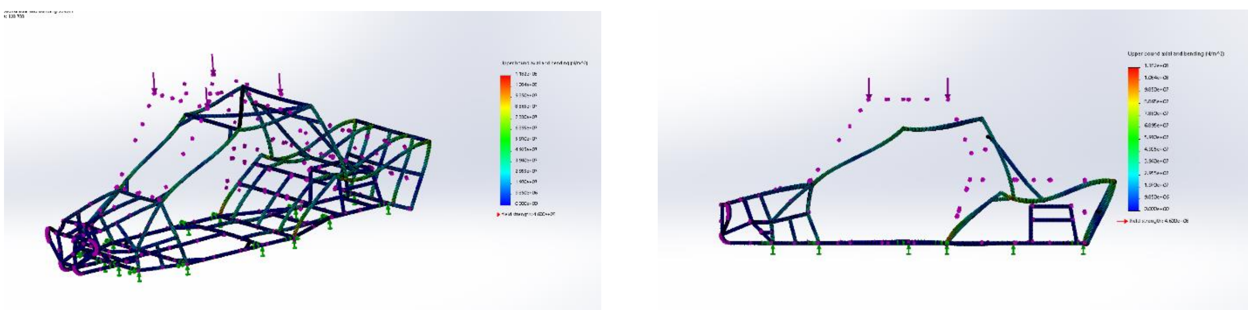


Figure 15

Above are the results for the stress plot

Displacement

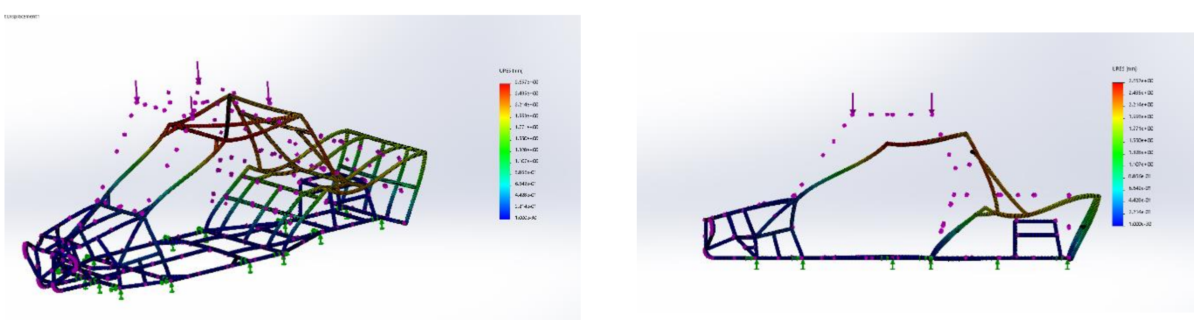
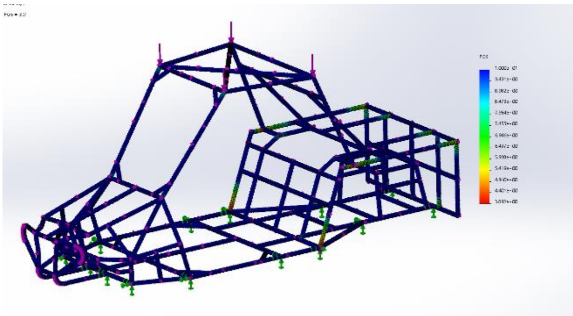


Figure 16

Above are the results for the displacement plot

Factor of Safety



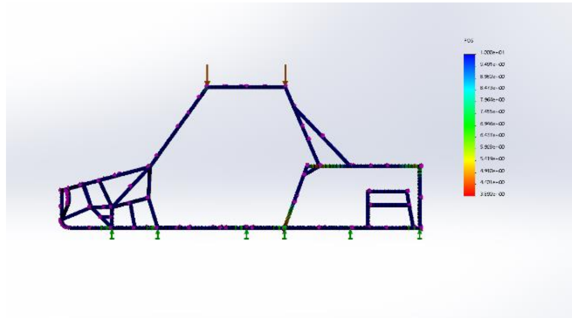


Figure 17

Above are the results for the factor of safety plot

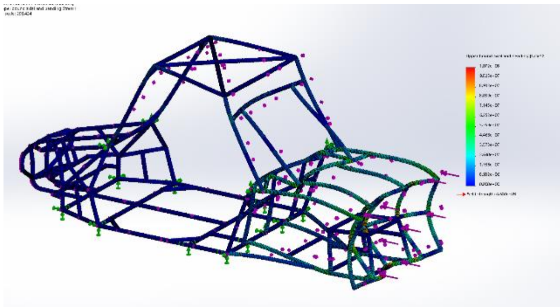
The top loading condition follows the same scenario as the front end collision. If the vehicle is to roll over, it will most likely hit a corner of the frame. The loading scenario applied in the simulation would be as if the car was dropped from the sky. So this is why I deemed this test as acceptable as well. Also the stress concentrations are located in the miter of the two tubes, the current frame has radius bends. So this load would be distributed through the tube and not be concentrated at the miter cut of the two tubes.

Rear Impact Collision

Calculations

- Mass
  - $\mathrm{m = (vehicle\ weight) + (passanger\ weight)}$
  - $\mathrm{m = 190lbs + 500lbs}$
  - $\mathrm{m = 690lbs = 313kg}$
- Force
  - $\mathrm{F = m * a}$
  - $\mathrm{F = 313kg * 6 * 9.81\frac{m}{s^2}}$
  - $\mathrm{F = 18{,}423.18N = 4141.70lb_f}$

Stress



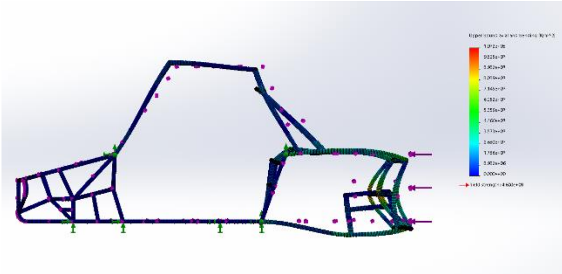
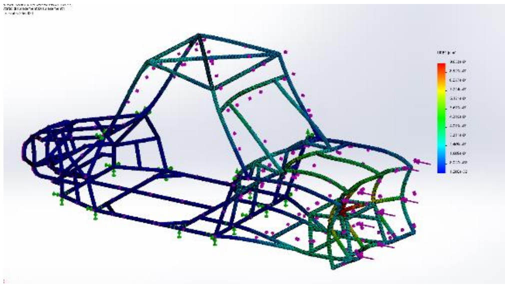


Figure 18

Above are the results for the stress plot

Displacement



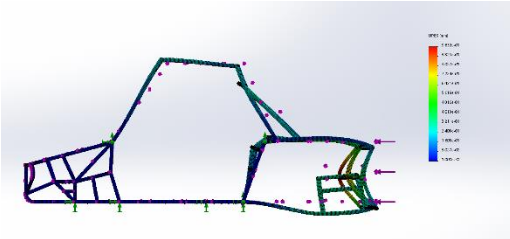
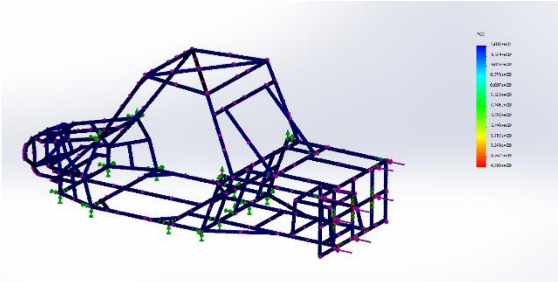


Figure 19

Above are the results for the displacement plot

Factor of Safety



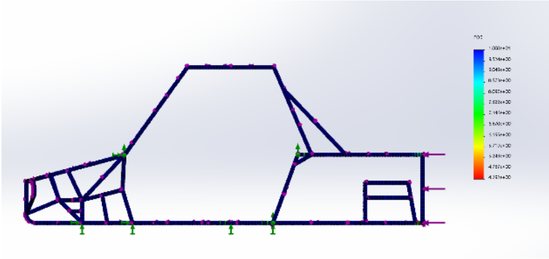


Figure 20

Above are the results for the factor of safety plot

The final crash simulation was a rear end collision. This simulation follows the same as the front impact, so I will not go into the specifics of explaining the setup. This is the least likely scenario since the UTV is not a road legal vehicle. So, the risk of a rear end collision is very low, if not zero. The only scenario we see as happening, would be reversing into something at speeds under 10mph. This scenario was an information simulation, as we do not see a large force being applied to the back of the vehicle given our end user. I chose to use a G-Load of 6, which I believe is very high and will not be seen as our base line. Realistically I see this number being around a 2, which would raise of minimum factor of safety substantially.

Factor of Safety Concerns

As addressed above, we see a very low factor of safety in the front collision and top impact simulations. The reason for these numbers being around 6 is because of the way the frame was modeled. We used a 3D sketch to create a weldment profile of the whole frame. Weldments in Solidworks will not work around a radiused bend. So we see strong stress concentrations in those mitered areas, where as the model (shown below on the right) the tube is actually radiused. This will allow for the stress to be distributed through the member. Without this strong stress concentration, the factor of safety would be around a 1.9-2.1 for both simulations. I feel comfortable accepting these results as we used a G-Load of 6. The vehicle will have a max speed of around 28-30mph, realistically we expect a G-Load of only 3-4 being applied. The reason we ran the simulation in a worst-case scenario, is to prove the frame is still above minimum factor of safety requirements in the worst conditions.

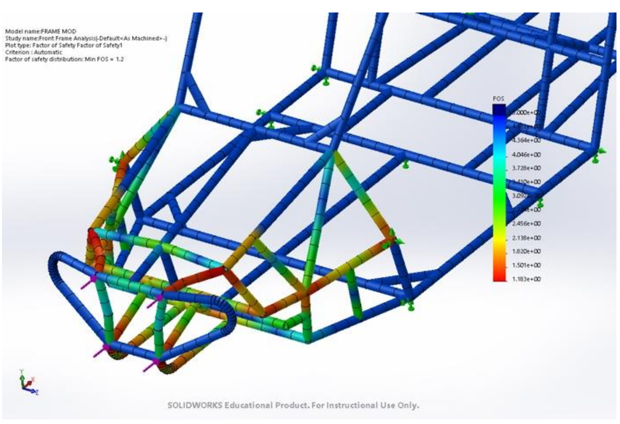


Figure 21

Above is a comparison of the model versus the actual frame

Build and Test

The group concluded early in the semester that the group would not be able to complete the fabrication of this UTV. Instead, we would do 3 things as a substitute; we would complete the design of the entire UTV, create process prints for next year's group, and complete a parts list for purchased components. The group, along with our advisor, felt that this would be plenty of work, and would set next year's group up nicely to complete the fabrication.

Test Procedure and Criteria

Since the frame was not built, we are not able to show any test results. However, the test procedure we will want completed by the following group will be as follows. Cope a test piece of tube and weld to another tube. After completing this, saw cut the weld in half and visually inspect for any cracks. This test should be done prior to the group welding any components onto the frame itself. This will ensure the group is capable of welding structurally sound welds, allowing the process to move forward for fabrication.

Final Frame Design

As stated above our group did not fabricate our frame, instead we shifted our focus to completely modeling the UTV in Solidworks. Upon creating this model, we would create process and step by step drawings to show how the frame will be fabricated.

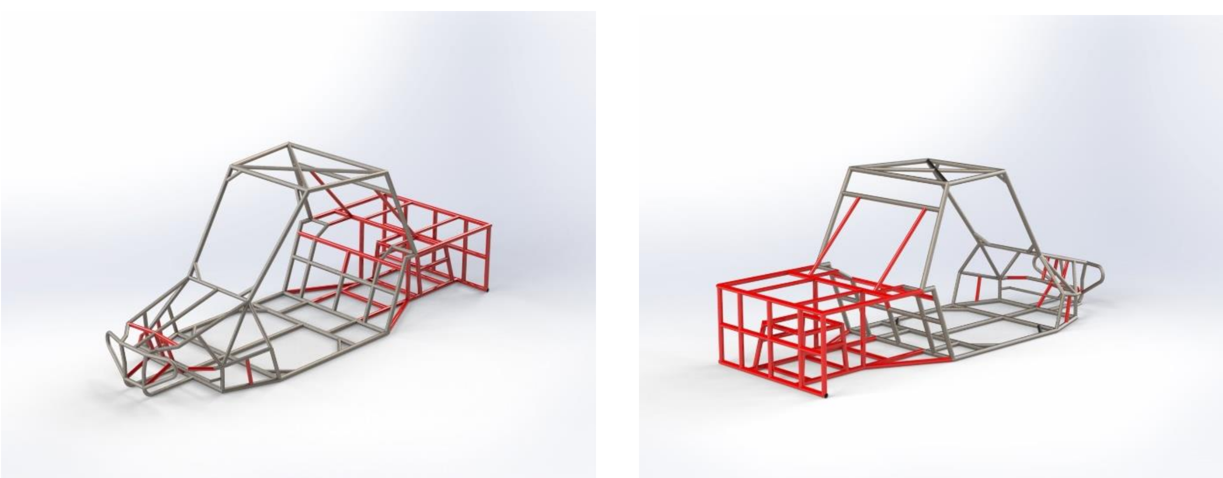


Figure 22

Above are a front and back rendering of the completed frame. The components in red are to be fabricated and welded to the current design (in grey)

Process Drawings

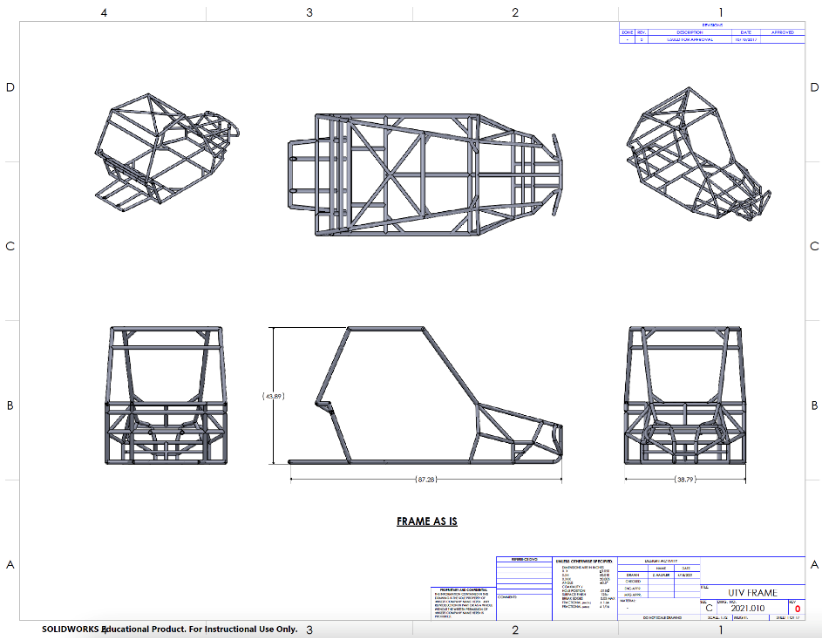


Figure 23

This is a drawing of the current frame as it sits from the previous group

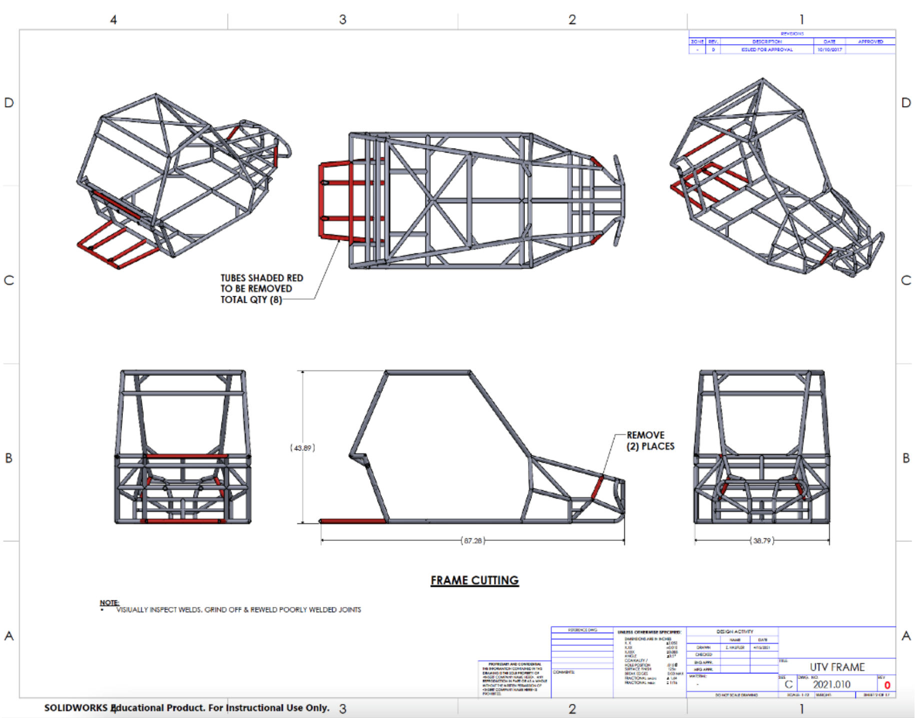


Figure 24

This drawing shows the components in red which are to be removed from the existing design

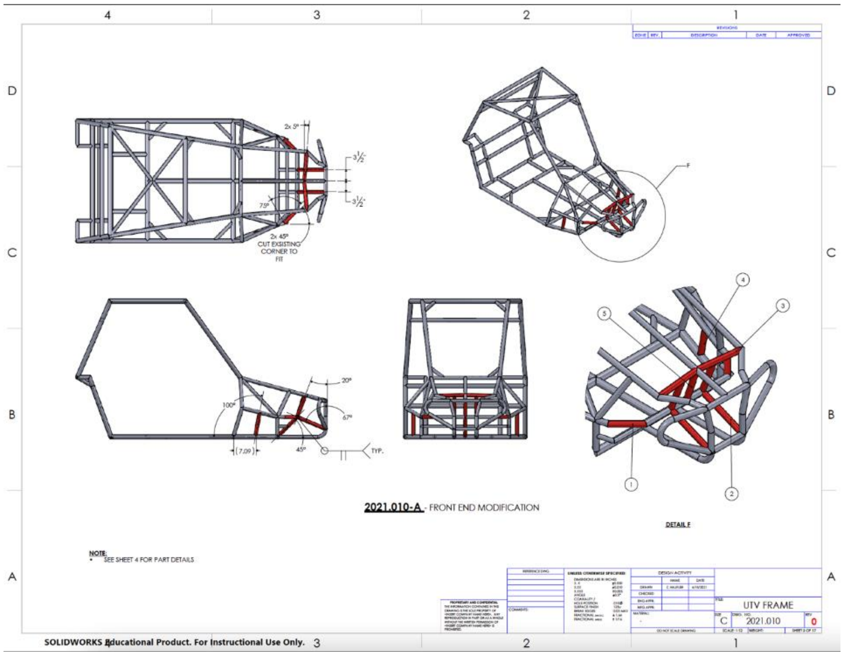


Figure 25

This shows the modifications in red to be added to reinforce the front end

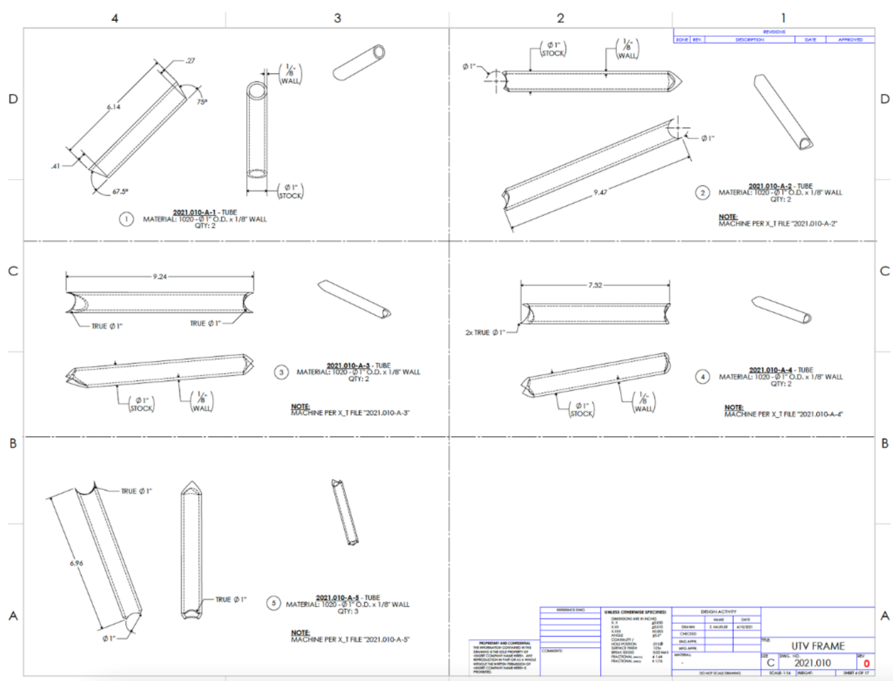


Figure 26

This drawing is part details for sub assembly 2021.010-A

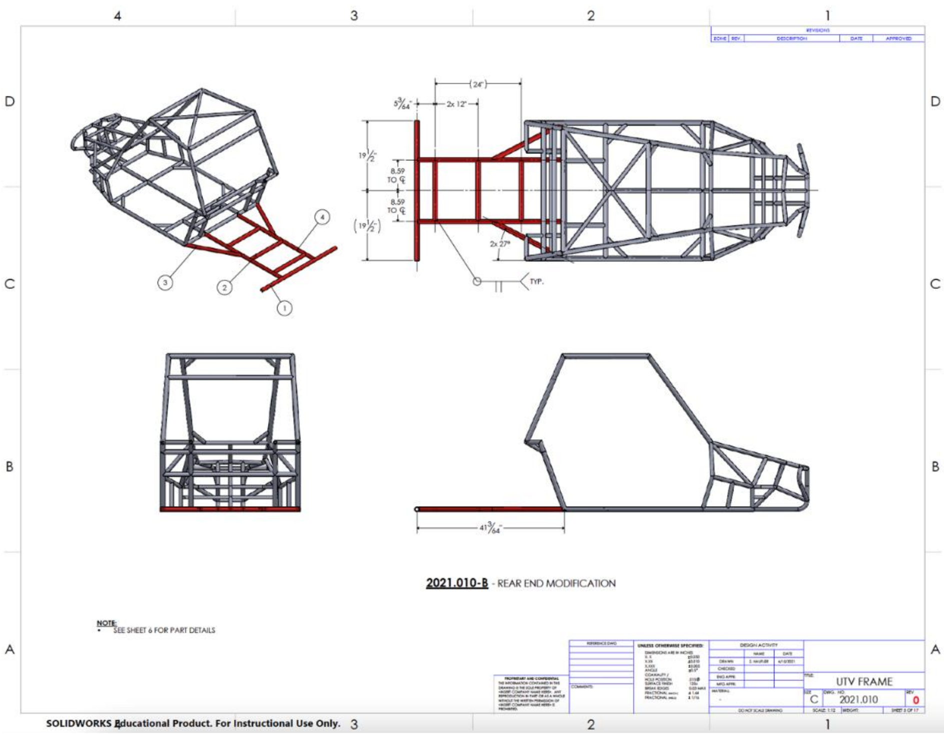


Figure 27

This shows the modifications in red to be added to support the engine

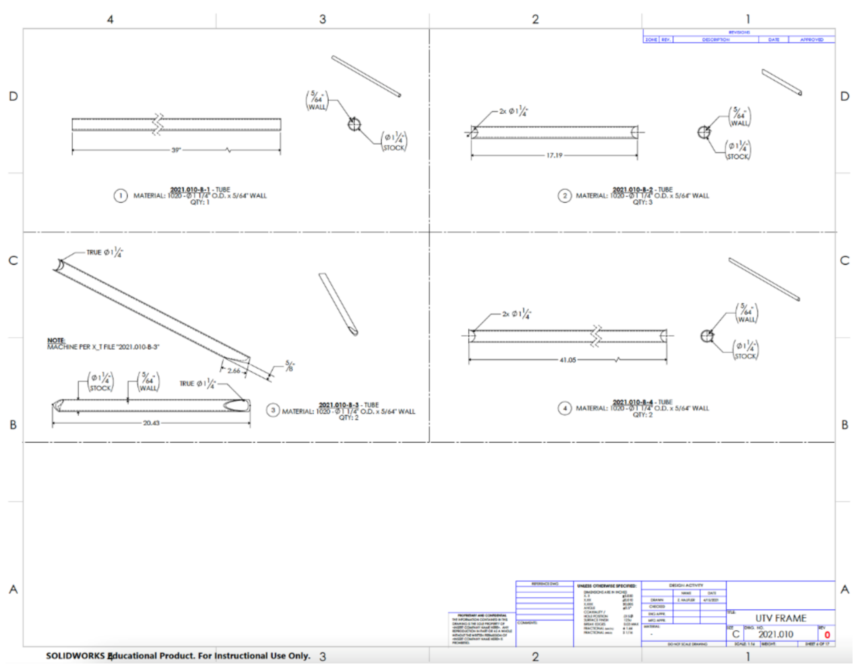


Figure 28

This drawing is part details for sub assembly 2021.010-B

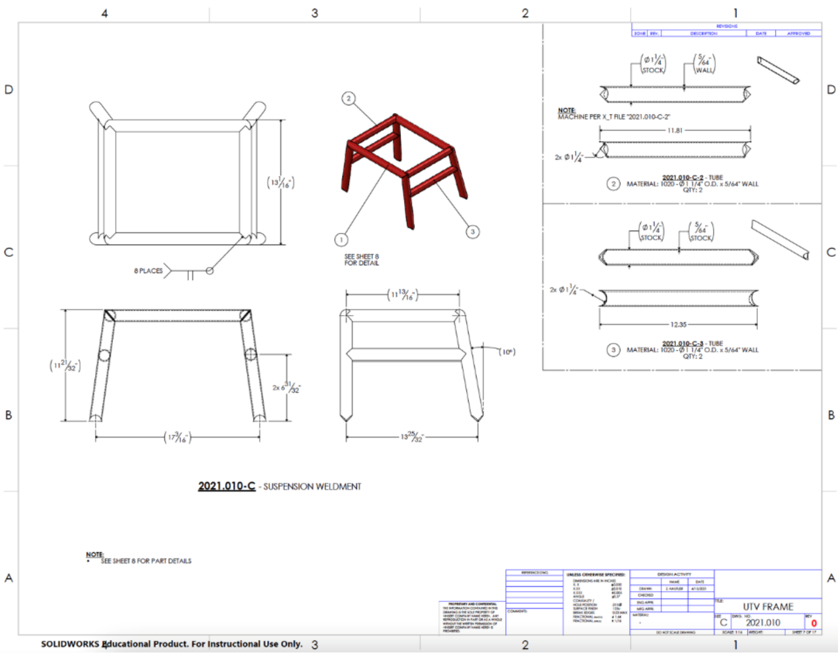


Figure 29

This is the suspension mount weldment

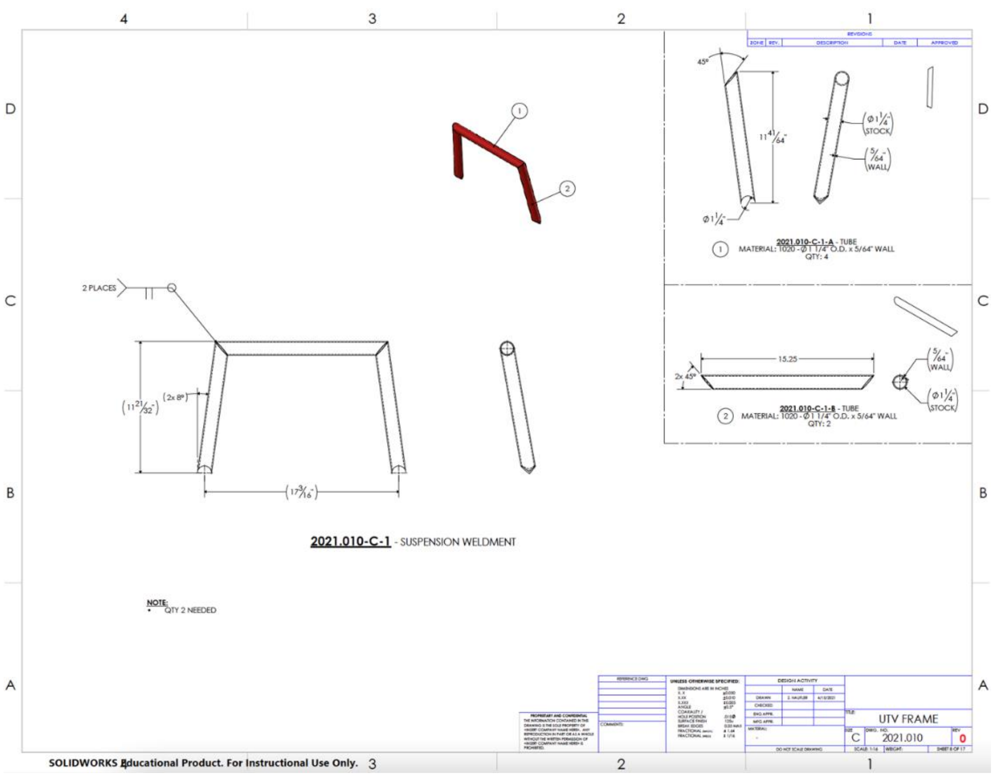


Figure 30

This shows the sub weldment for subassembly 2021.010-C

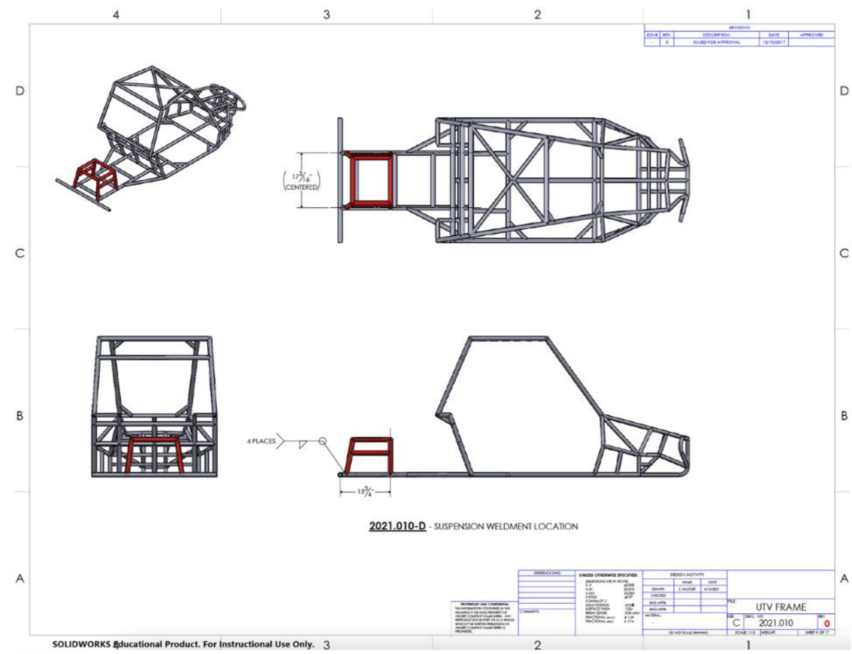


Figure 31

This drawing is for the location of the suspension mount (2021.010-C)

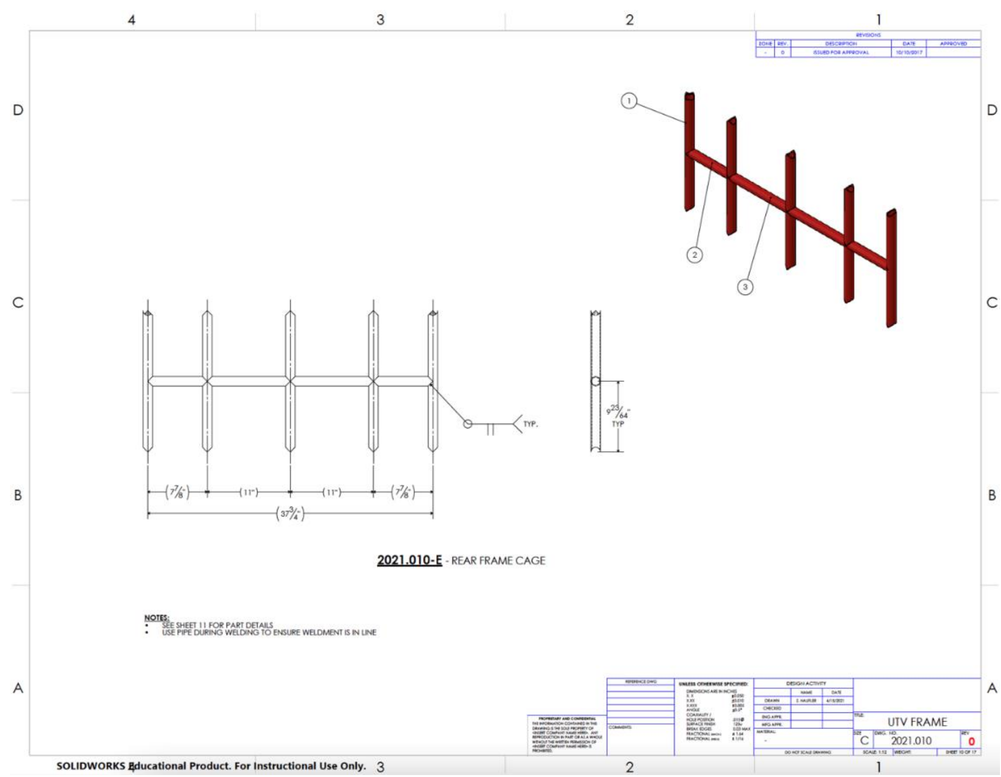


Figure 32

This drawing is the subassembly to support the rear of the frame

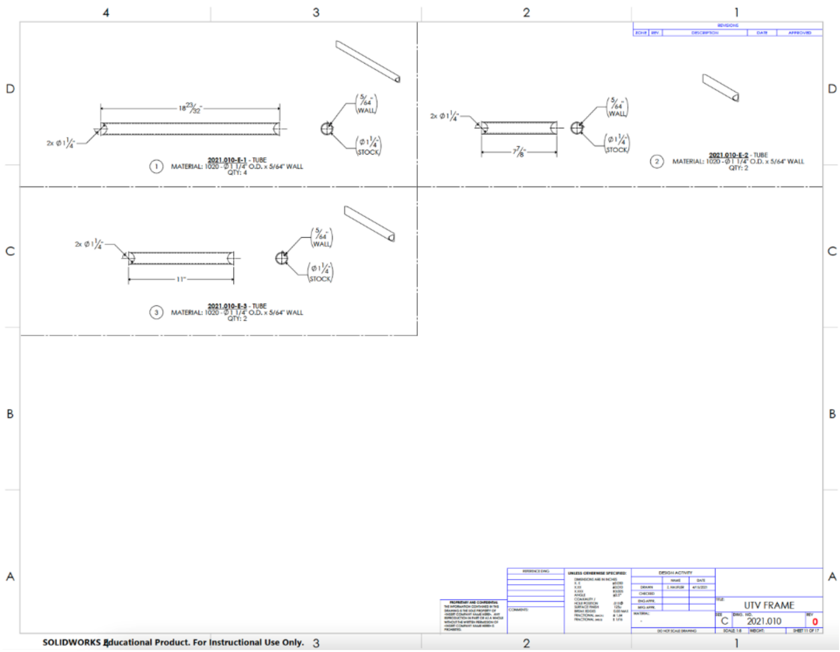


Figure 33

This drawing is the individual part details for subassembly 2021.010-E

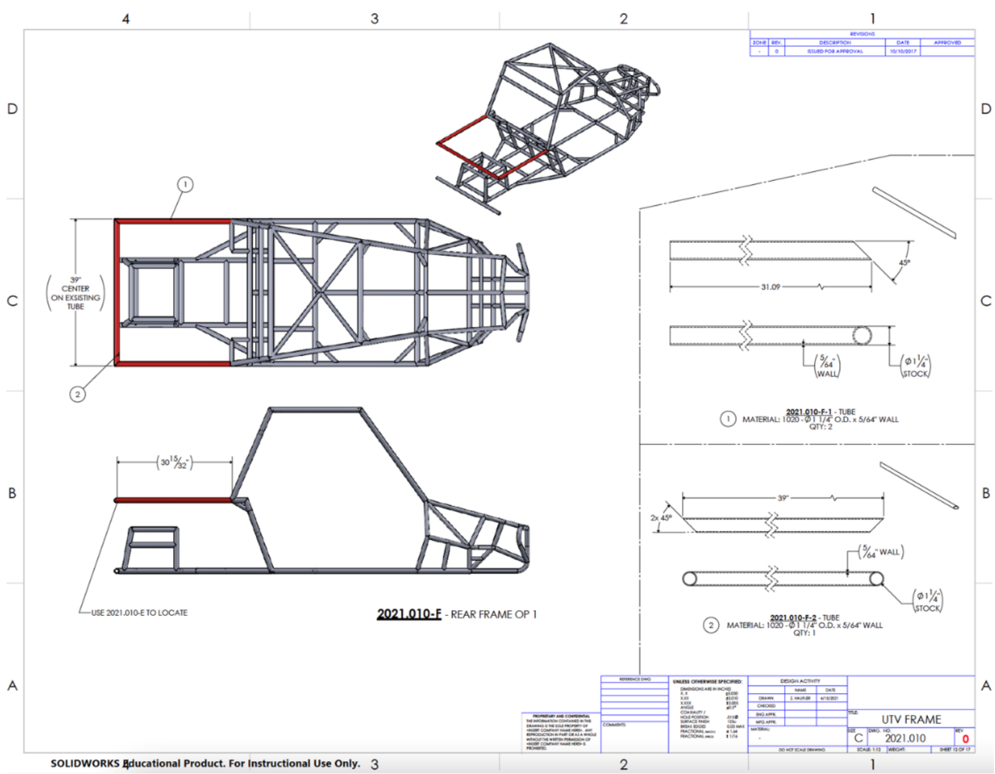


Figure 34

This drawing details the bed of the frame

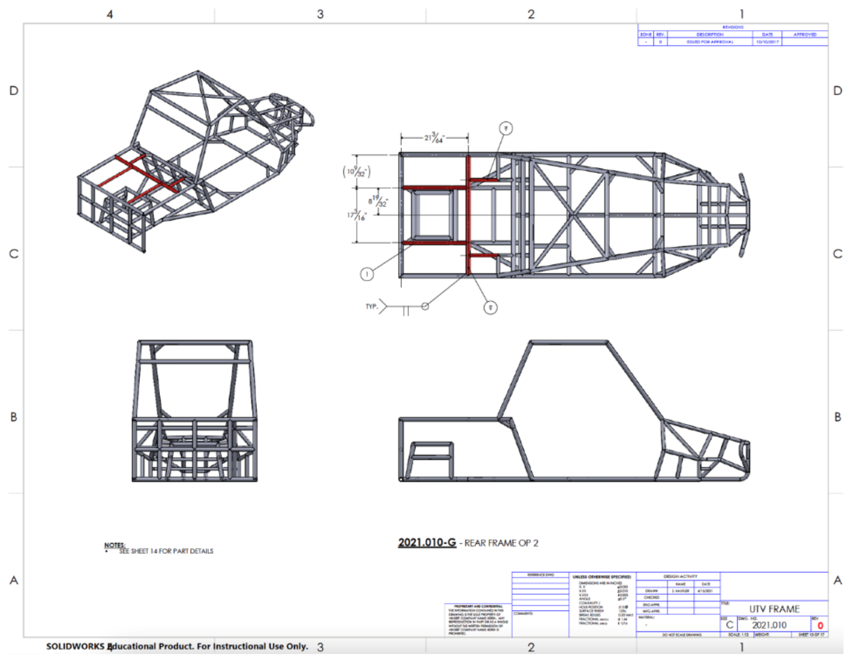


Figure 35

This shows the supports for the drop in basket to hold cargo

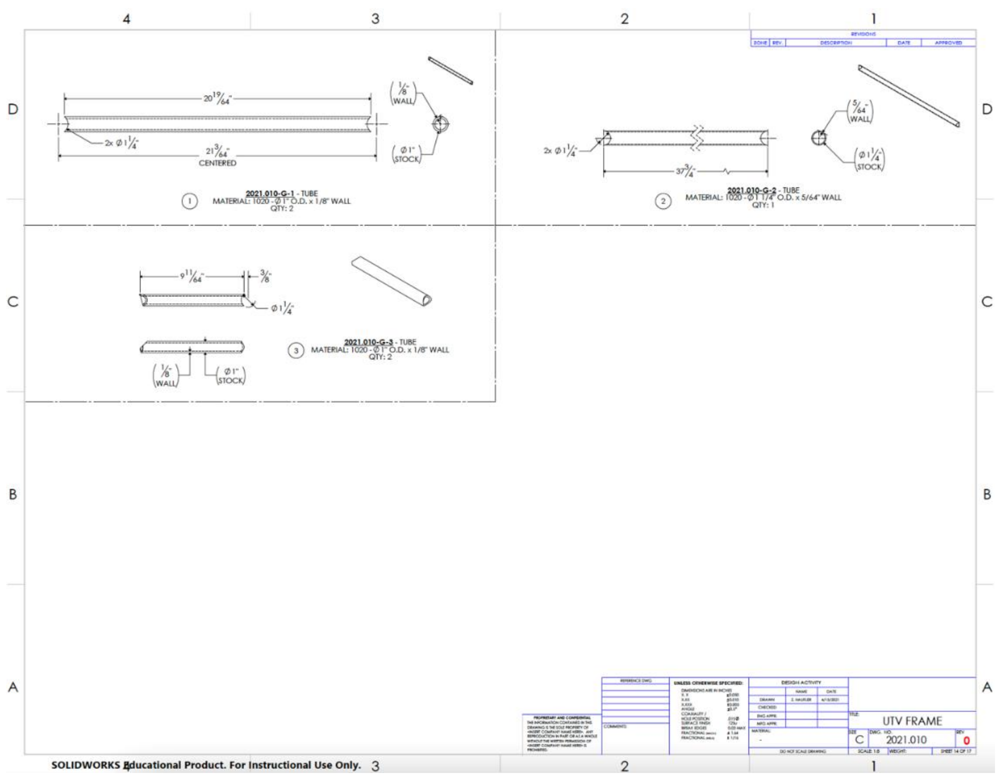


Figure 36

This drawing is part details for sub assembly 2021.010-G

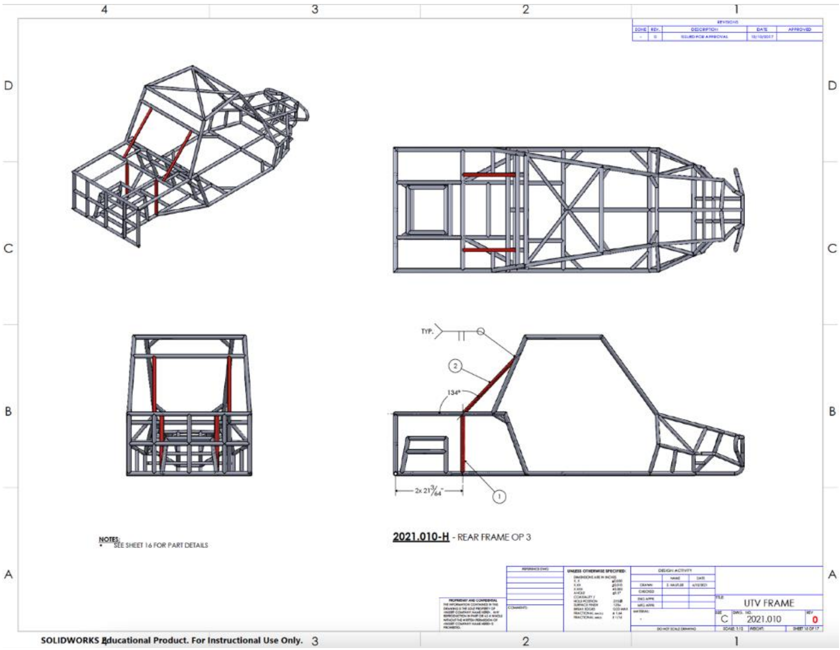


Figure 37

This shows the modifications in red to support the roll cage of the frame

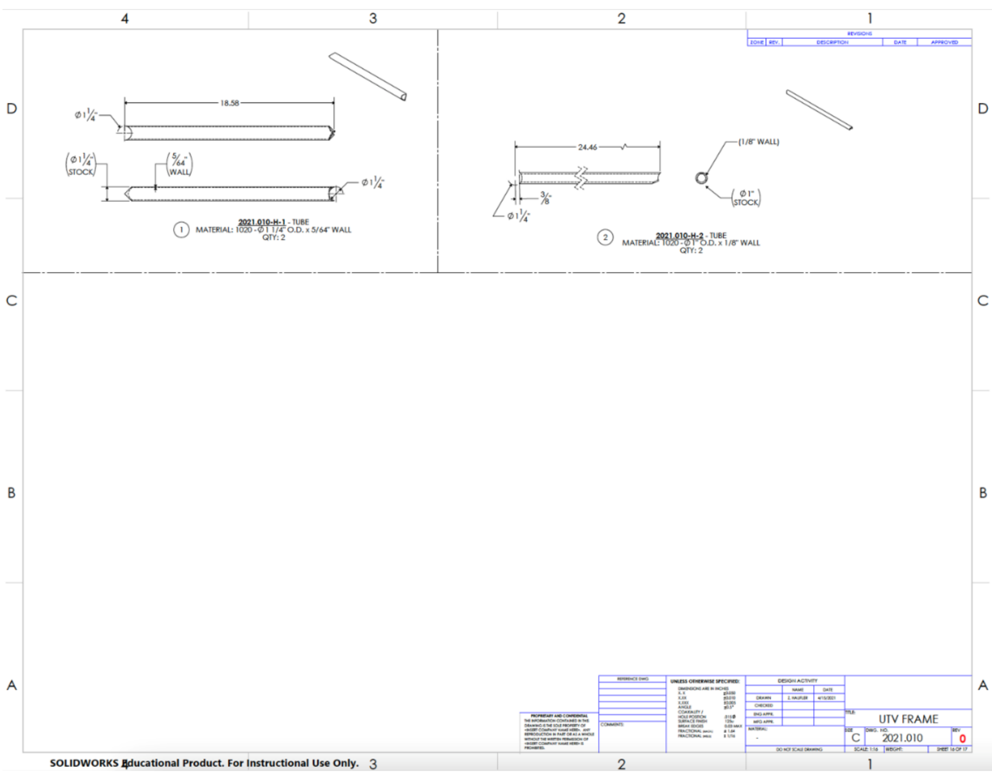


Figure 38

This drawing is part details for sub assembly 2021.010-H

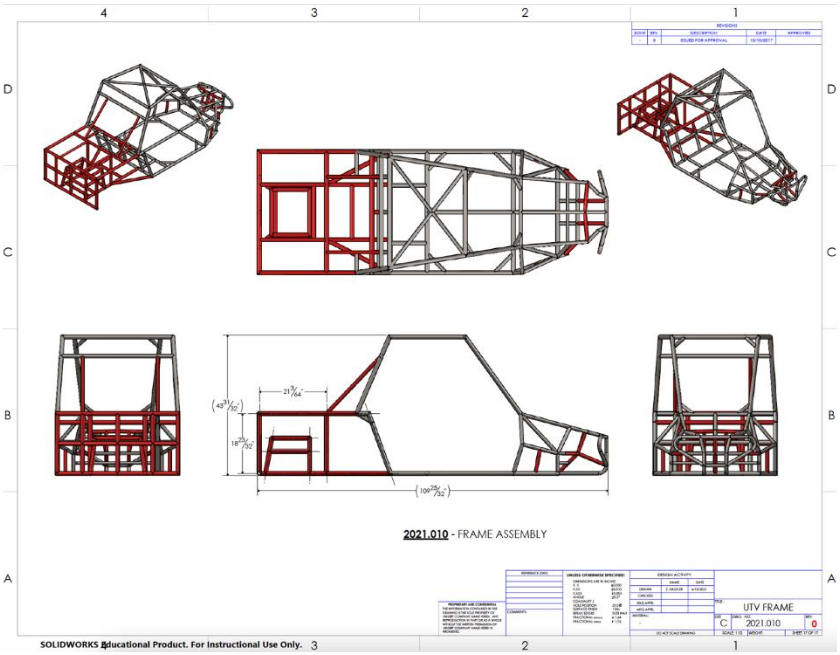


Figure 39

This drawing shows the finished frame, with all added components shaded red

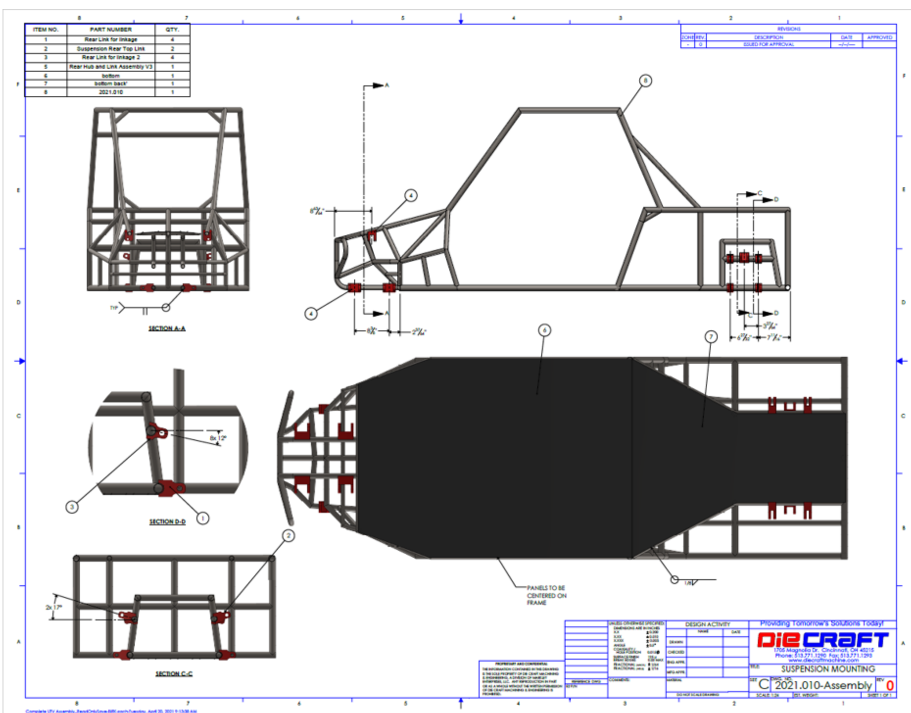


Figure 40

This drawing details the location of the suspension blocks to be welded to the frame, as well as the bottom skid plate weld detail

The process drawings about show multiple sub-assemblies being built, to eventually reach the finished design. I believe this is the best way to detail the modifications, opposed to doing them on one drawing and creating more confusion. The red shaded components on each drawing are the ones to be added, they then turn grey after the subassembly is complete. A handful of the parts have complex angles and will need to be laser cut or machined. I added a note for those parts to reference the x_t for them to be machined. The rest of the components are coped to fit, so dimensions are not critical.

Project Management

Project Budget Limit vs Actual

Given the purchased components that the group already has, and the frame already having been built, we set a budget limit of $10,000 to complete this project. Given the change of scope for the project, below is the timeline we originally had in place.

Key Milestones

Remaining Components Put on Order	11/30
Components Arrive	1/15
Frame Modifications	1/20
Assembly and Testing 50%	3/20

Table 2

The proposed budget was ten thousand dollars, however with the current design, the group believes this is an overestimate. A new proposed budget would be around five thousand dollars, but this depends on how next year's group sources the parts.

The schedule changed from the fall semester since the overall scope of the project changed. The group met expectations for the schedule as discussed with our advisor.

Works Cited

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