Design and Development of a Human Powered Vehicle: NASA Competition

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Donors: Great Bicycle Shop, University Cycles

TEAM 17

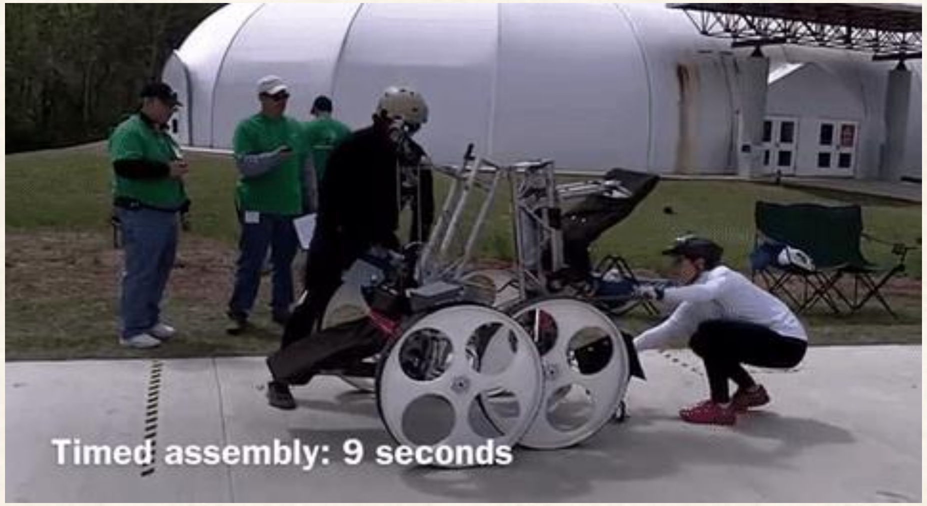
The Competition Basics

Prototype a vehicle that ...

- Is human-powered
- Accommodates two people
- Has off-road capabilities
- Is ‘small’ and ‘light’
- Is safe

Needs Statement:
“There needs to be a ground vehicle powered by fit male and female drivers that is capable of competing in the NASA Human Exploration Rover challenge.”

SUCCESSES



PITFALLS

FIGURES 2-5. PURDUE-CALUMET WINNING COMPETITION FOOTAGE[1]

Component Morphology

Design chassis

- Frame style, material, suspension, collapsibility, seat orientation

Design of drivetrain

- Chains, belts, reciprocating lever transmission
- Two-wheel vs. all-wheel drive
- Separate or combined drivetrains for two drivers

Steering

- Steering wheel, hand levers
- Two-wheel or all-wheel steering

Brakes

- Disc brakes, drum brakes, rim brakes

Design of wheels

- Materials, size, shape, tread

Rhode Island School of Design

- 2nd place at the 2016 competition
- Excellent online documentation
- Approval from RISD team to use their online webpage(s) as resources for our design

Figure 7: RISD Rover 2016

Frame Morphology

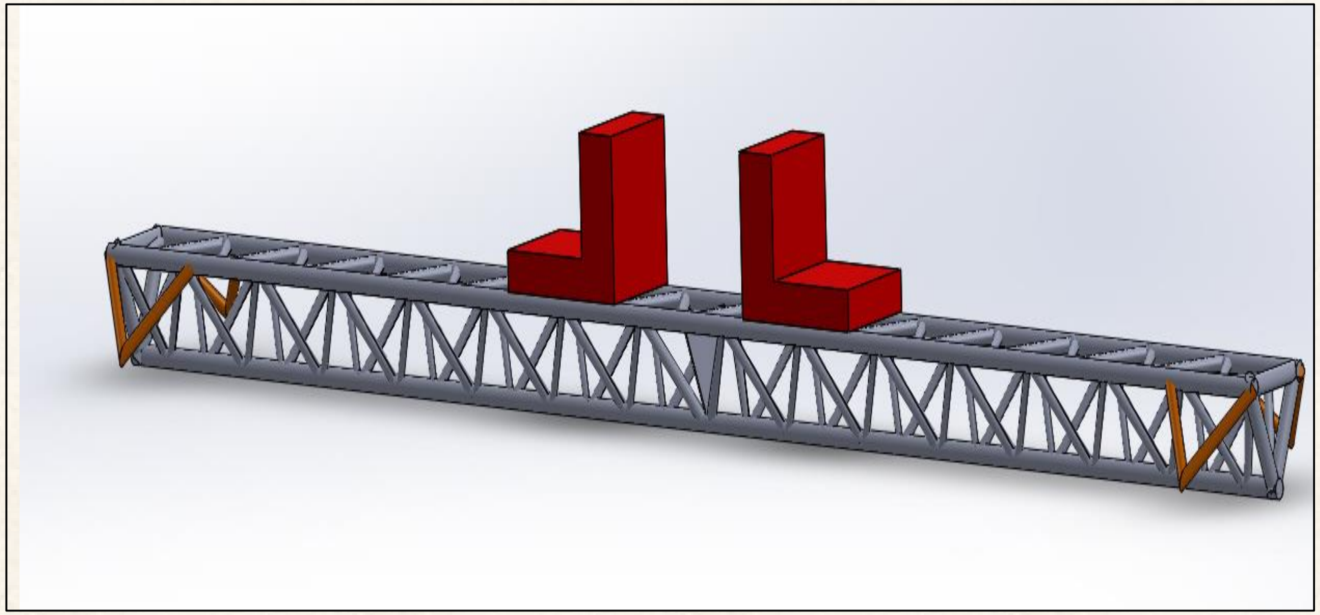


Figure 7: Selected Frame Morphology

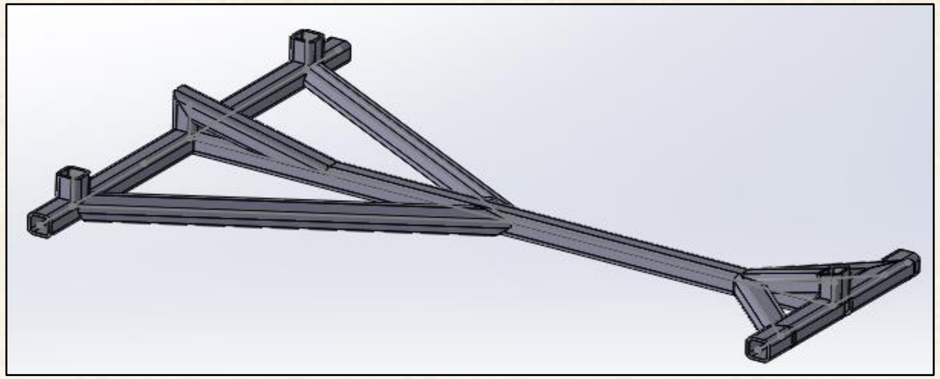


Figure 8: Alternate Concept 1

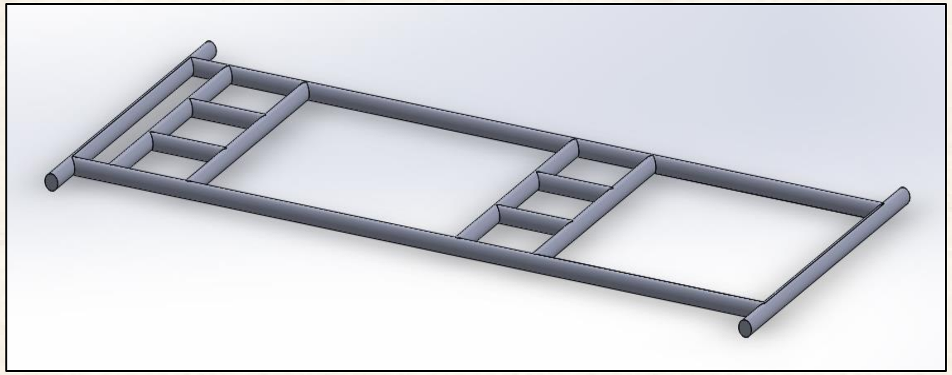


Figure 9: Alternate Concept 2

Current Frame Iteration

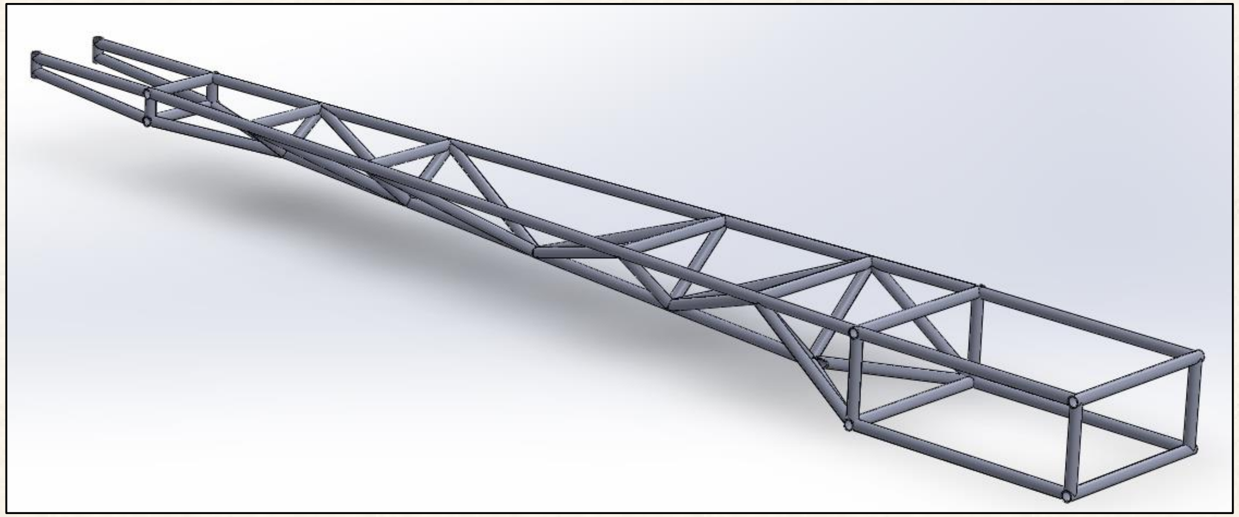


Figure 10: Current Frame Iteration

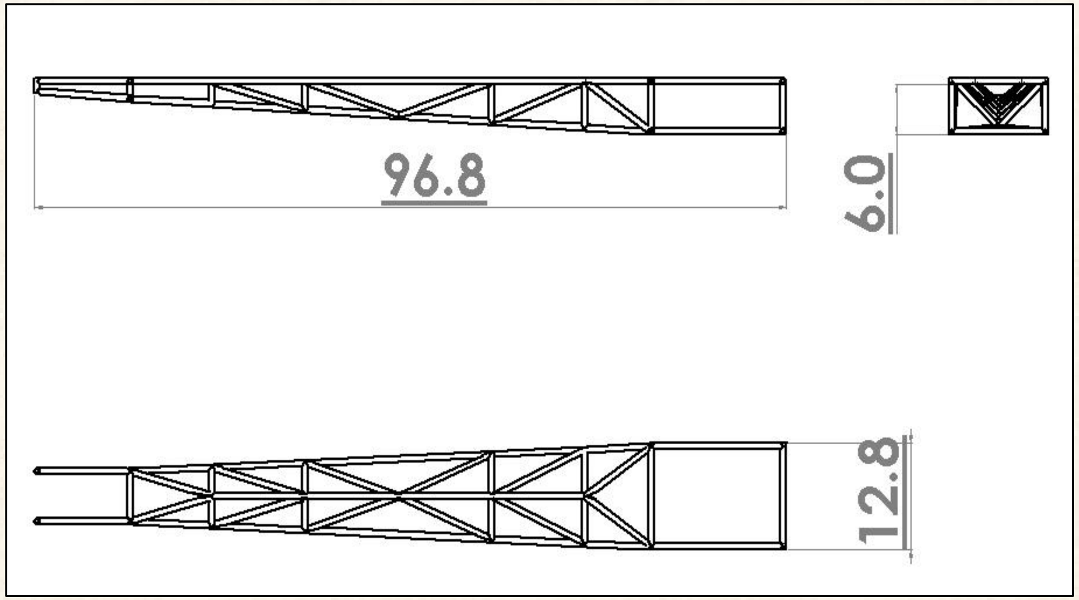


Figure 11: Current Frame Iteration *figures in inches

*Frame overall dimensions based off RISD and Seating Calculations (attached)

Tube selection Analysis

Chromalloy Steel Round Tubing

- Strength to weight ratio
- Common Usage
- Weldability
- Availability

Profile Selection (round vs square and dimensions)

- Weldability
- Availability
- Length between joints and profile varied until

Factor of safety of 1.4 achieved

12" member length used as baseline for frame design

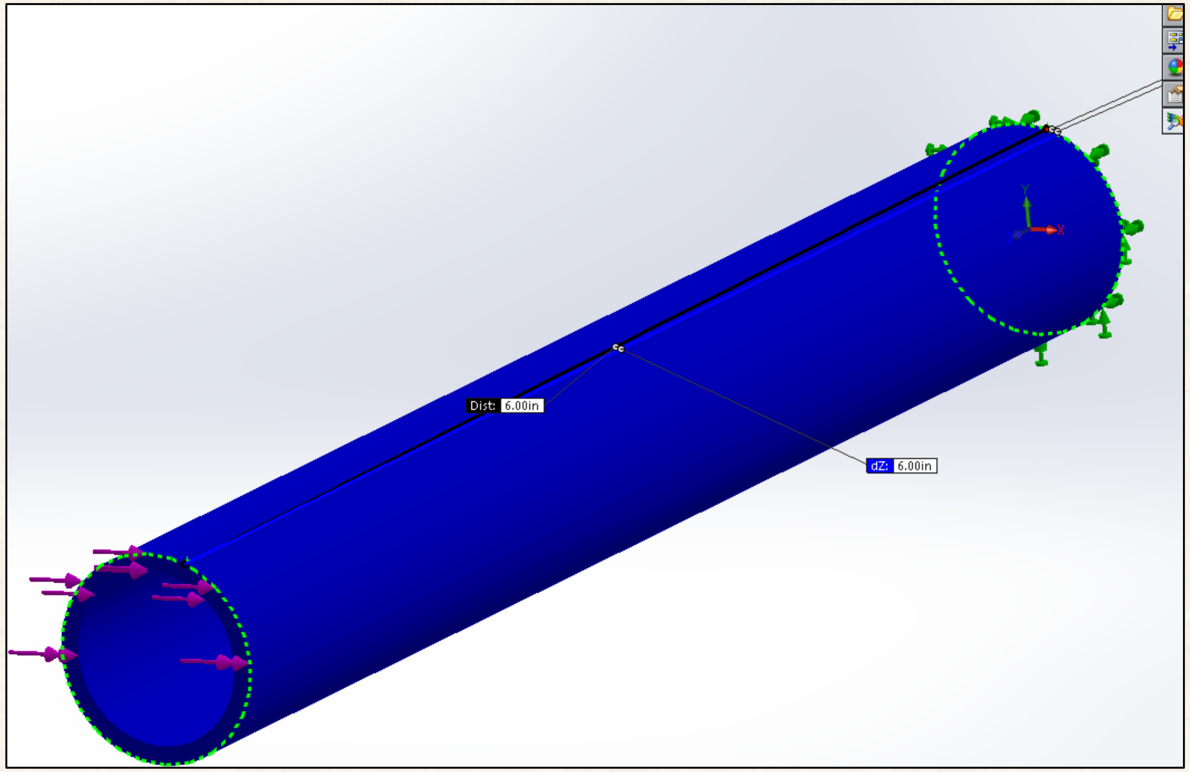


Figure 12: tubing selection analysis
Final profile 0.75"OD, 0.065" Wall

Frame Analysis

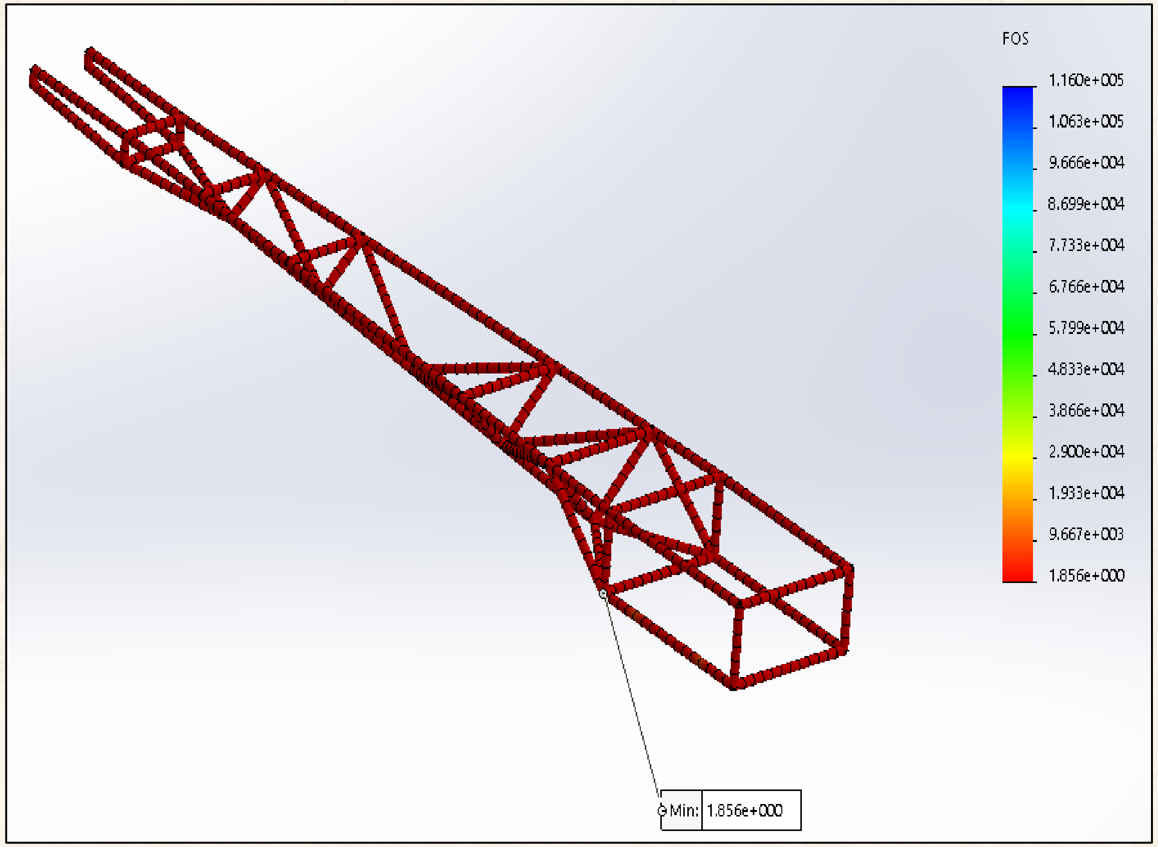


Figure 13: Factor of Safety Plot (Minimum 1.8)

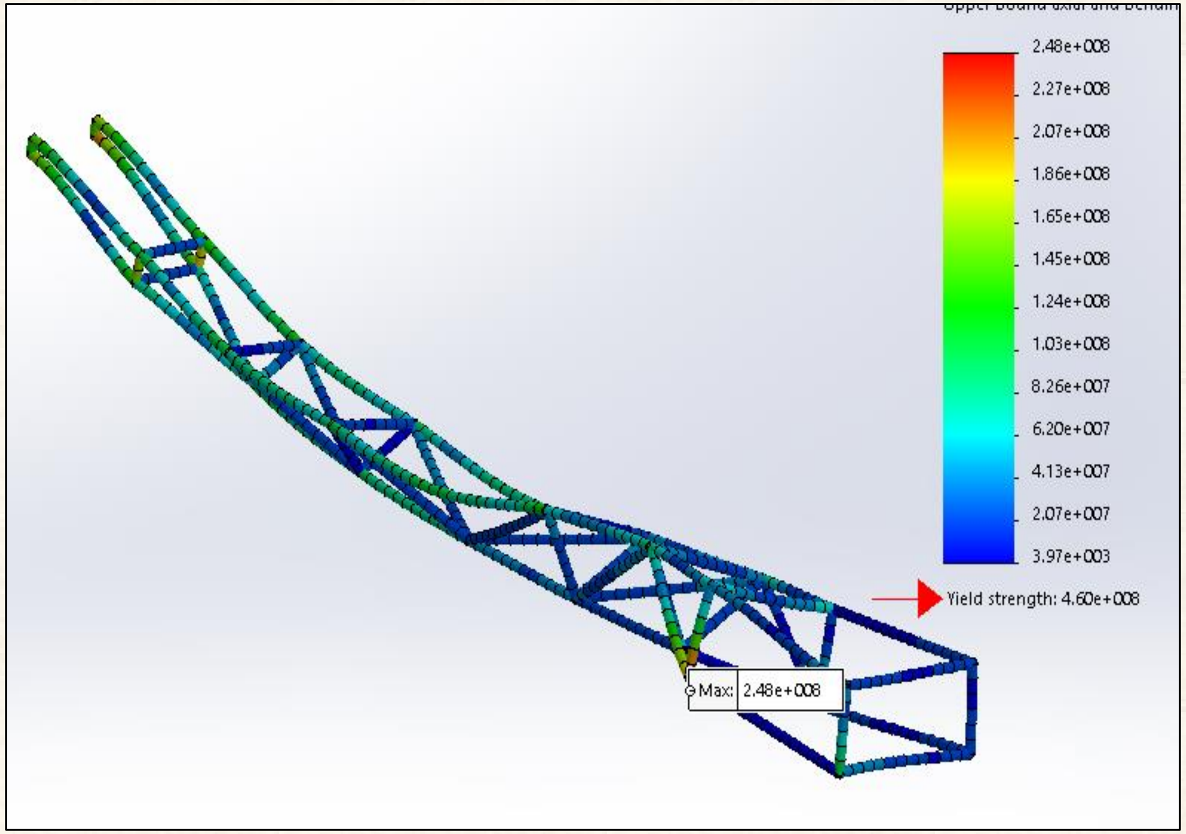


Figure 14: Von Mises Stress Plot (Maximum 280 KSI)

Frame Analysis cont.

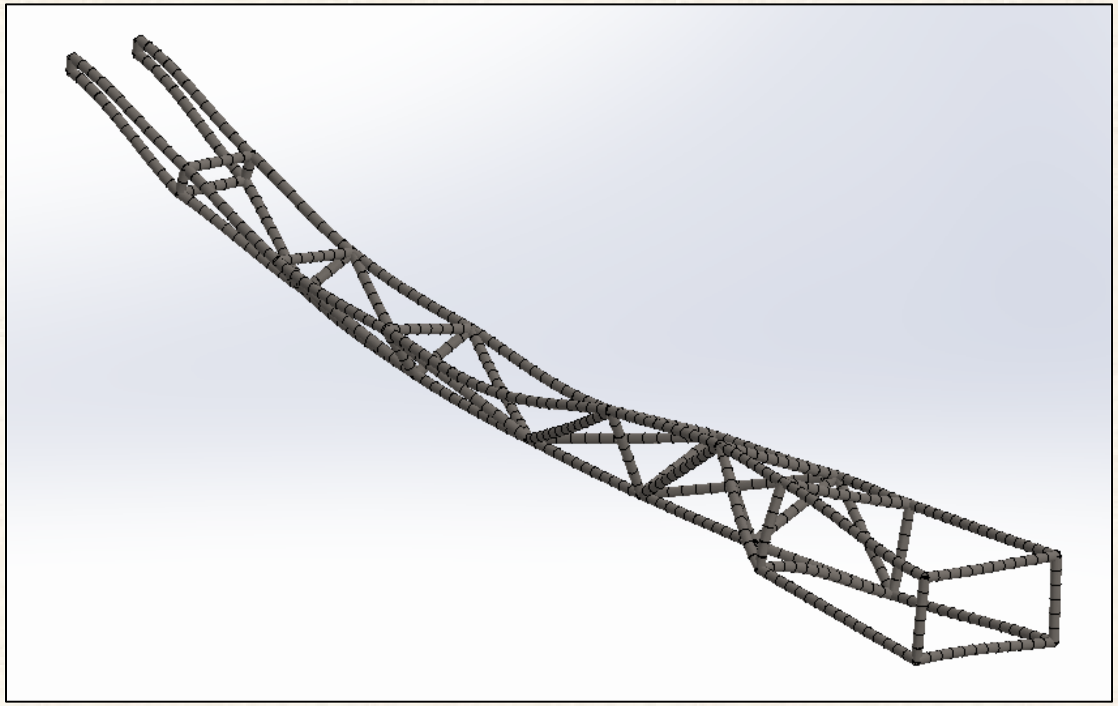


Figure 15: Deformation animation (4.86 mm max)

Member Total Length: **52 ft. (rounded up)**

Cost per 5ft length : $24.38

Total cost estimate: **$270** (plus shipping) [X]

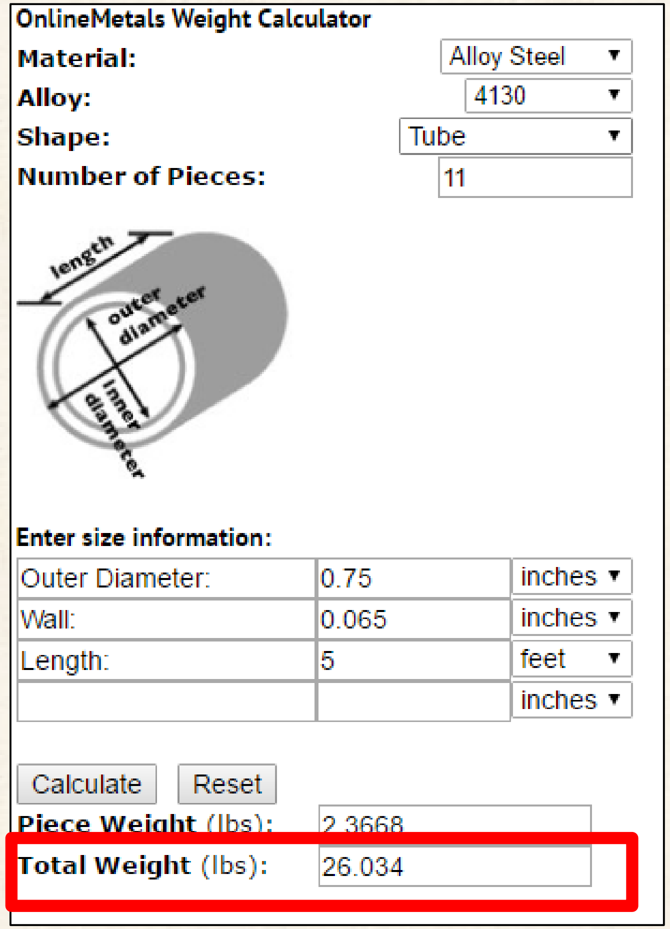


Figure 16: Weight Estimate [X]

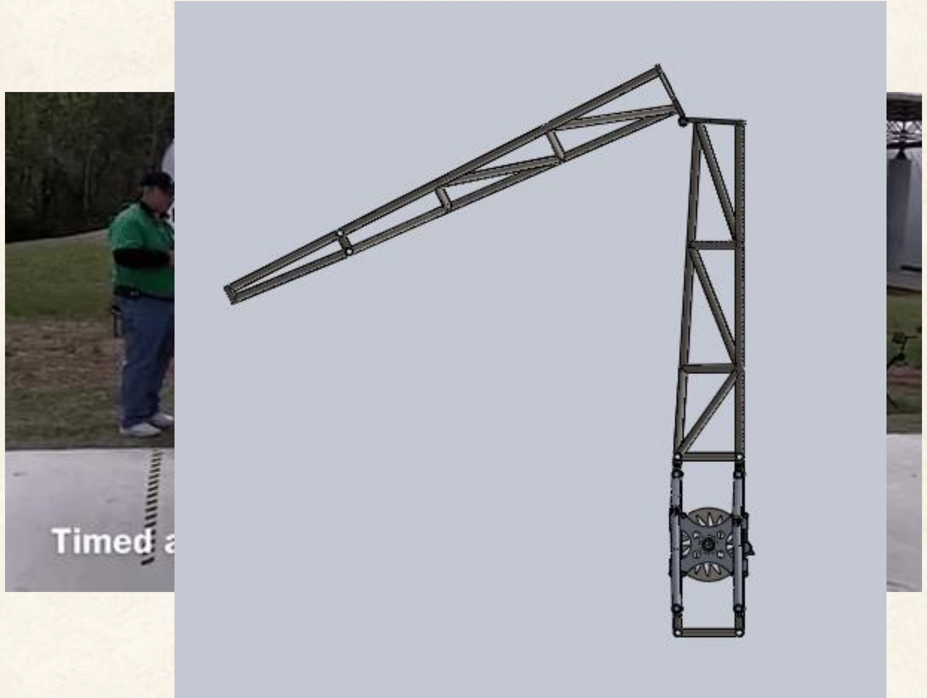
Collapsibility

Constraint: Rover must fit within a 5 x 5 x 5 cube

Solution: Folding Chassis Joint allows rover to fold

- 2 - 3/8 in. triangular plates
- Hinges welded to bottom
- Material: water jet cut A36 steel
- Welded onto the midsection of the chassis

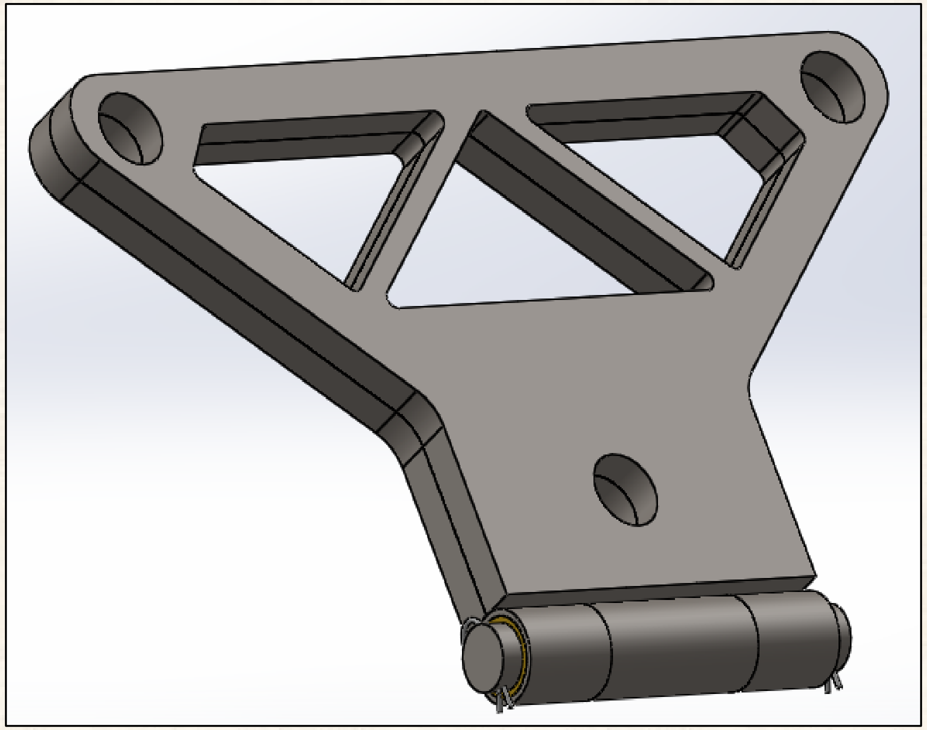
Folding Chassis Joint Assembly



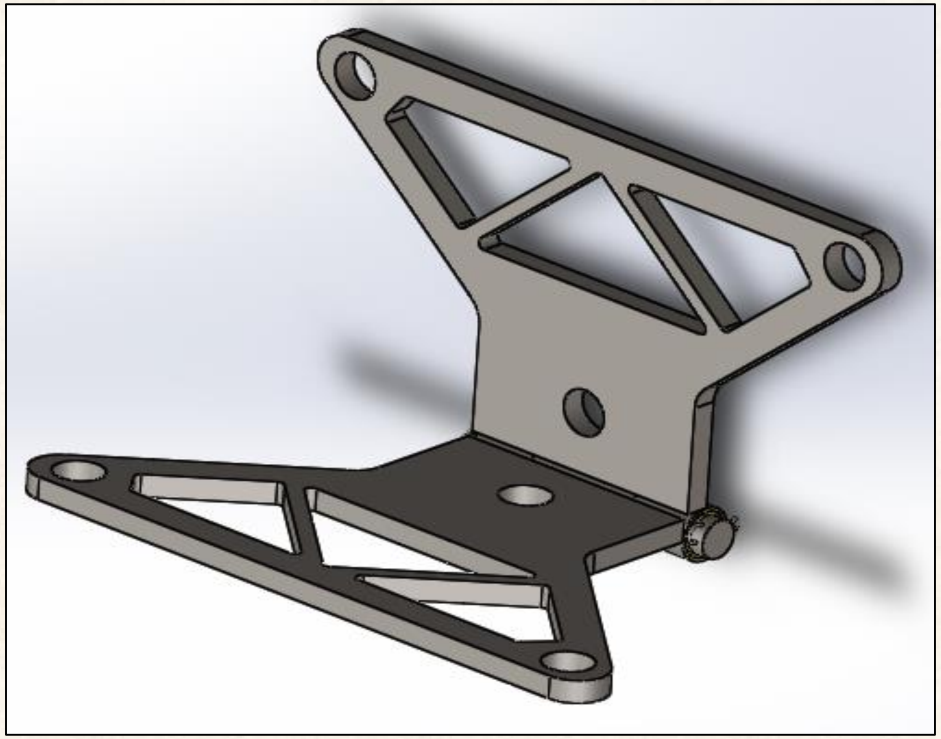
Figures 17-19: Chassis Fold

Folding Joint CAD Assembly

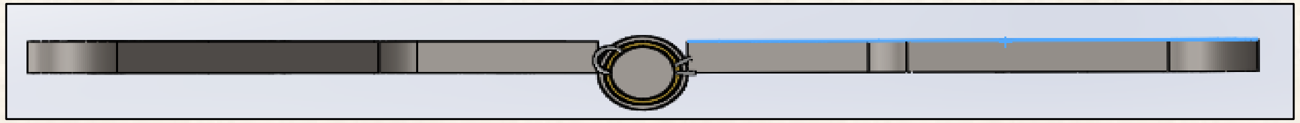
Closed Joint Assembly



Open Joint Assembly



Open Side View



Figures 20-22: Folding Joint

Folding Joint: FEA Analysis

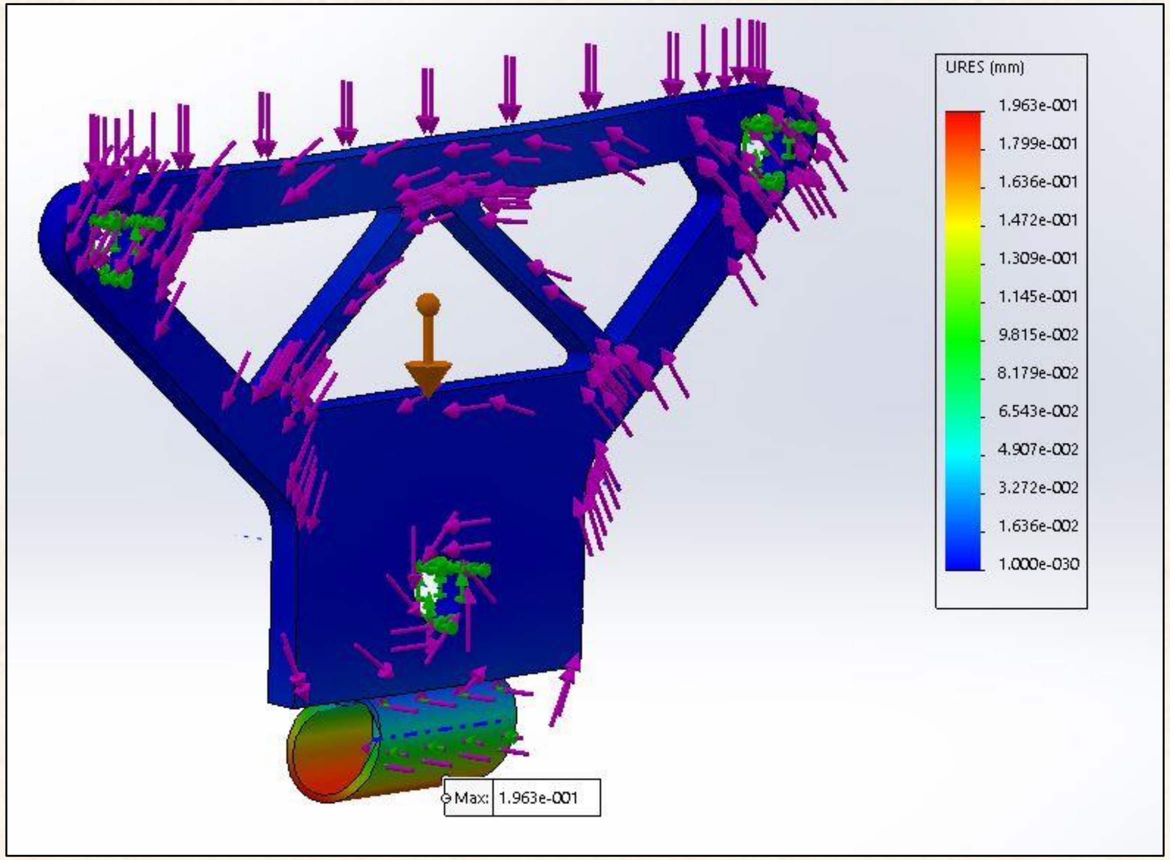


Figure 25: Folding Joint Analysis

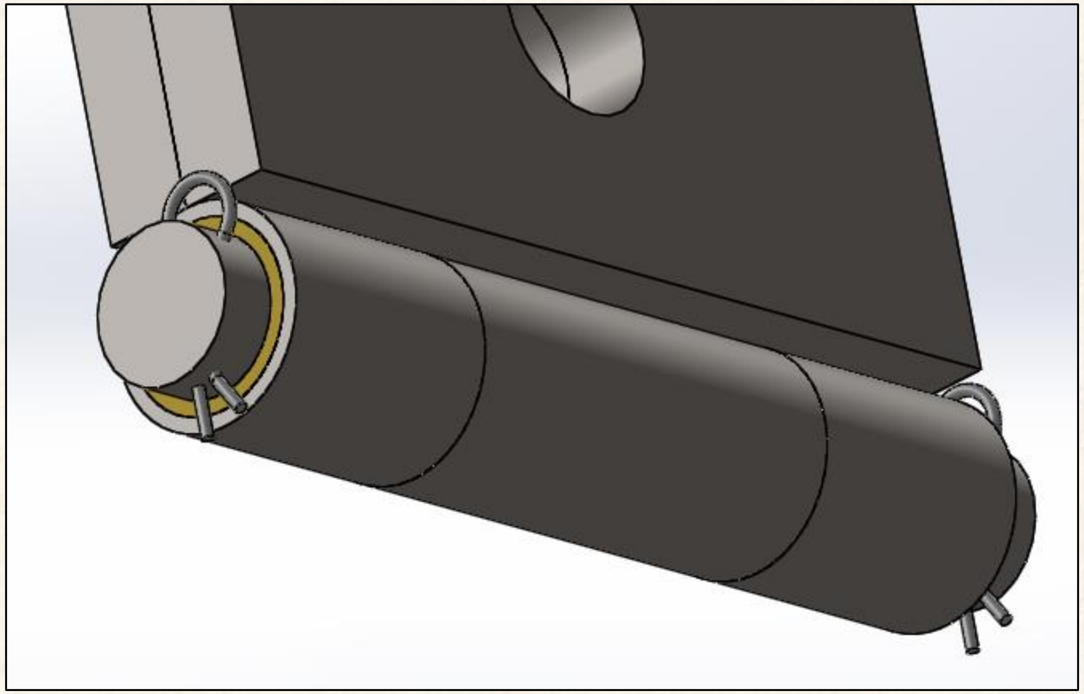
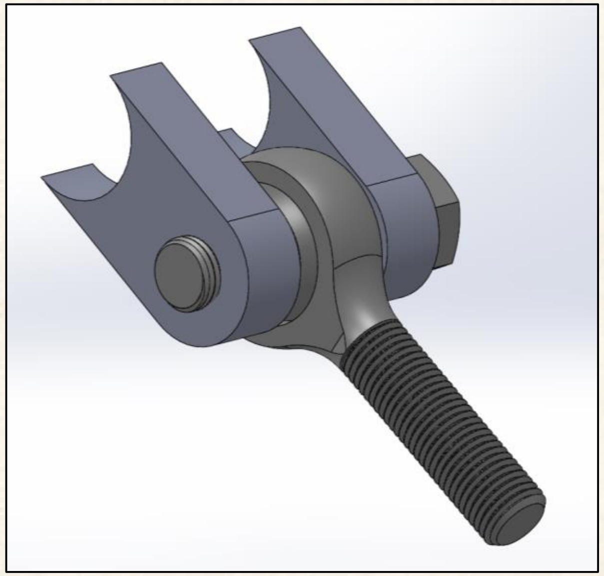


Figure 26 : Hinge

Attachment Tabs

- Metal tabs on two both sides of a Heim Joint
- Through research we found that Heim joints would fit our needs by providing flexibly in some ways and the restraint we need in others



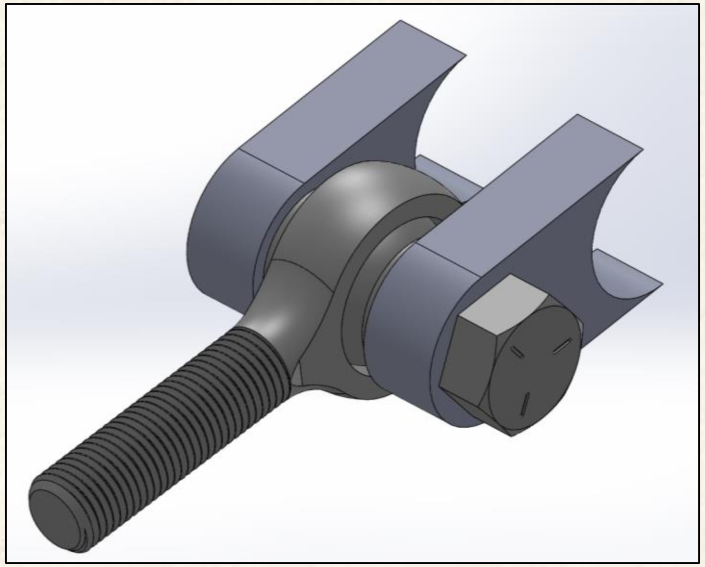


Figure 26-27: Steel Tabs

Tab Analysis

- No real challenges but that part is used in multiple places

- Chromalloy for material, largest stress areas would be the welds holding the tabs to the frame or the area directly around bolt hole

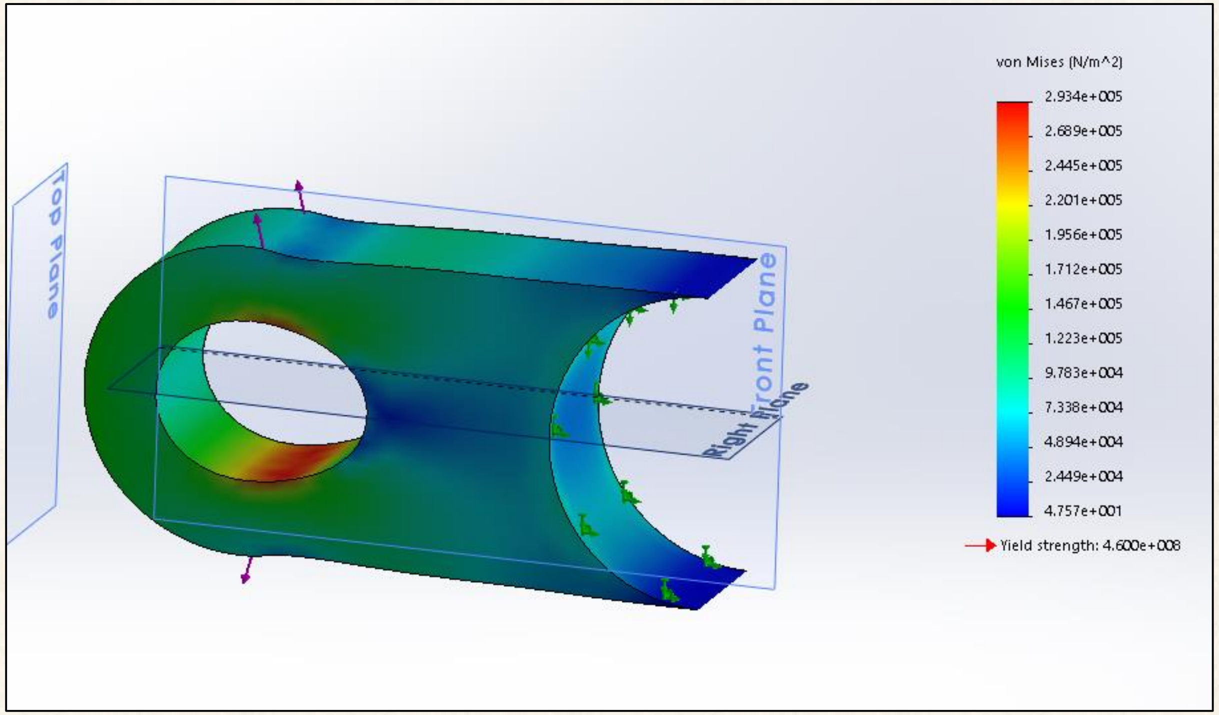


Figure 28: Tab Analysis

Double Wishbone Suspension

Figure 29: Upper A-Arm

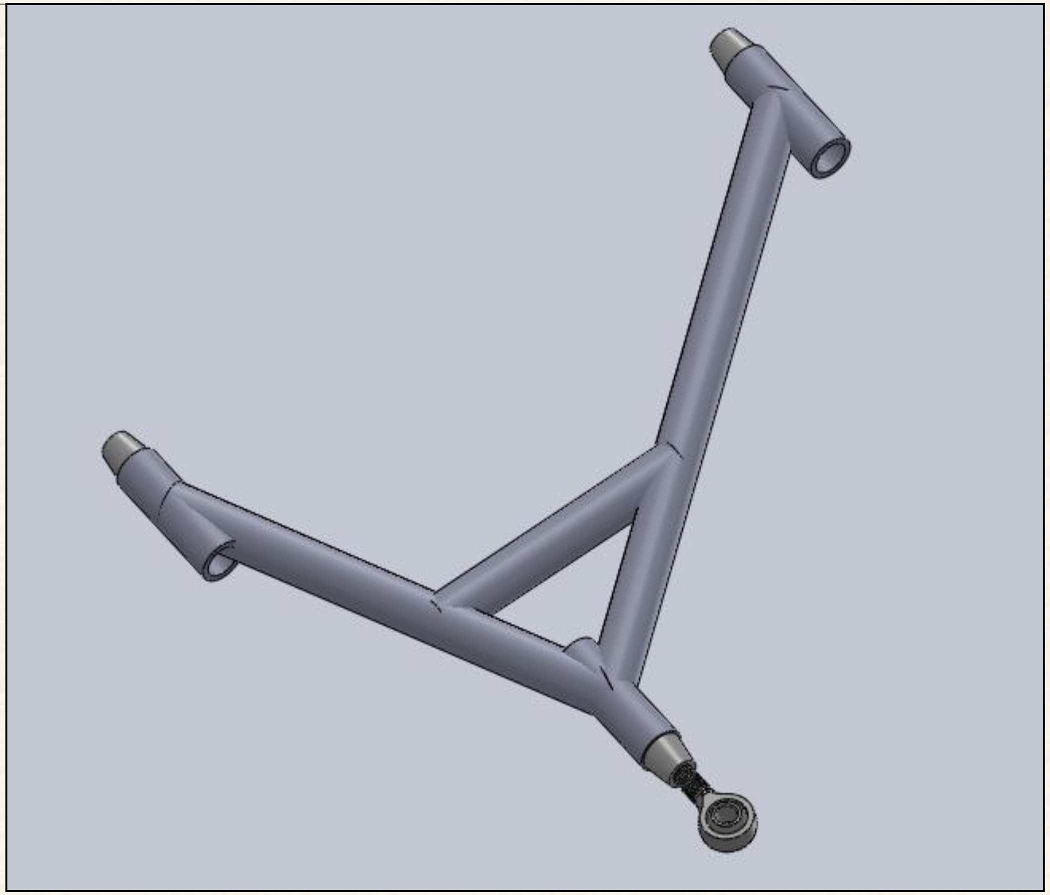


Figure 30: Lower A Arm

Suspension

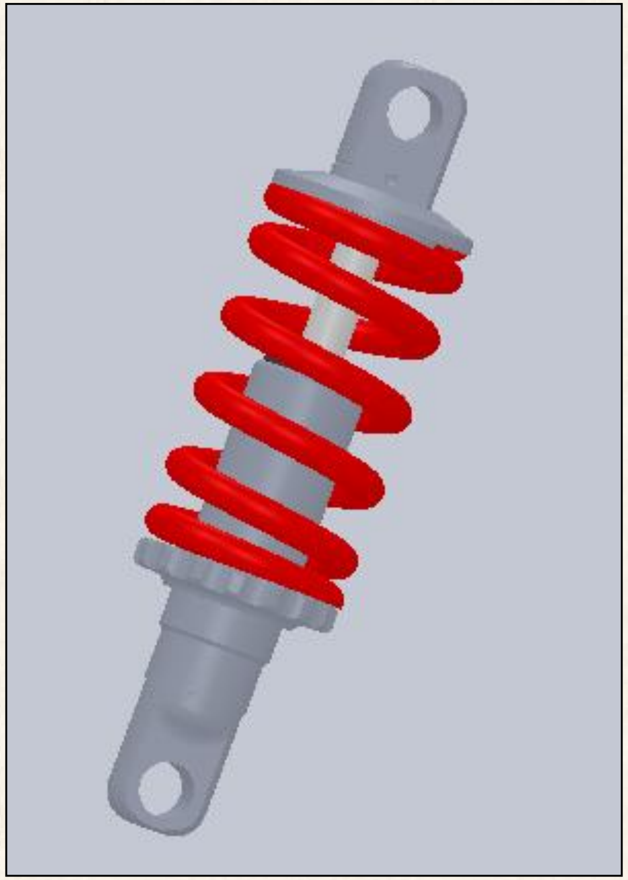


Figure 31: Shock

Simple hub designed to hold the wheel in place and attach steering

- Connects to A-Arms on top and bottom
- Connects to steering link in the rear

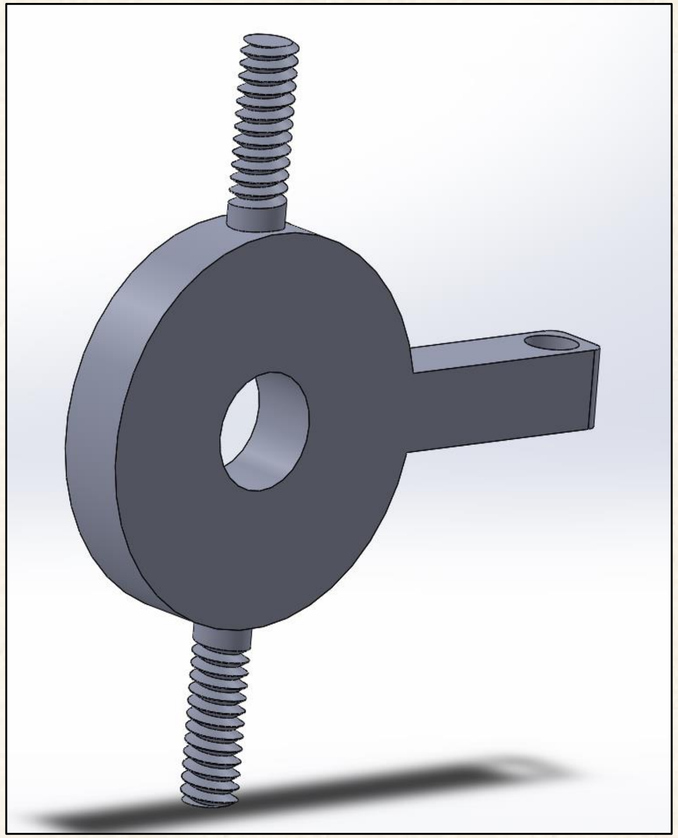


Figure 32: Hub

Suspension

A-Arm Angle	Clearance Gained	Minimum Wheel Size
10°	1.6 inches	26.8 inches
15°	2.3 inches	25.4 inches
20°	3.1 inches	23.8 inches
25°	3.8 inches	22.4 inches
30°	4.5 inches	21.0 inches
35°	5.2 inches	19.6 inches
40°	5.8 inches	18.4 inches
45°	6.4 inches	17.3 inches

Table 1: The Angle of the A-Arm and it's impact on Clearance

Front Drive Train Morphology

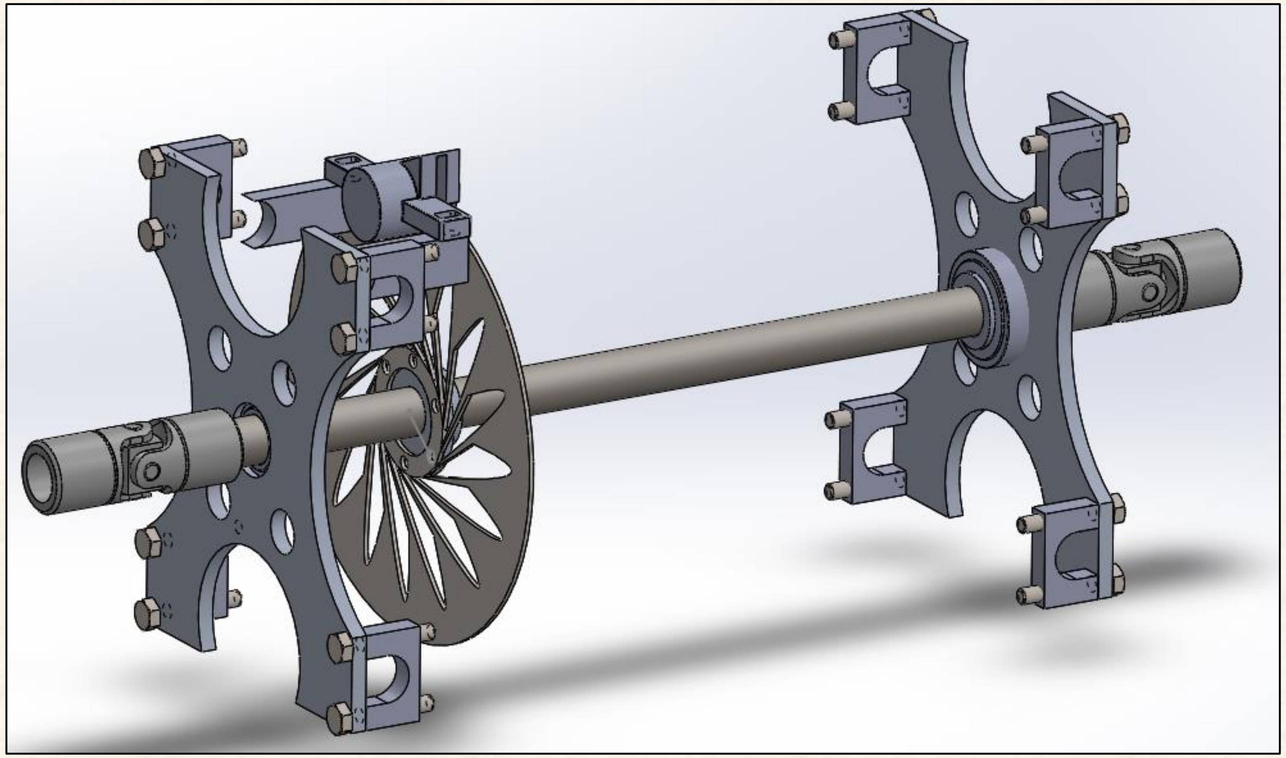
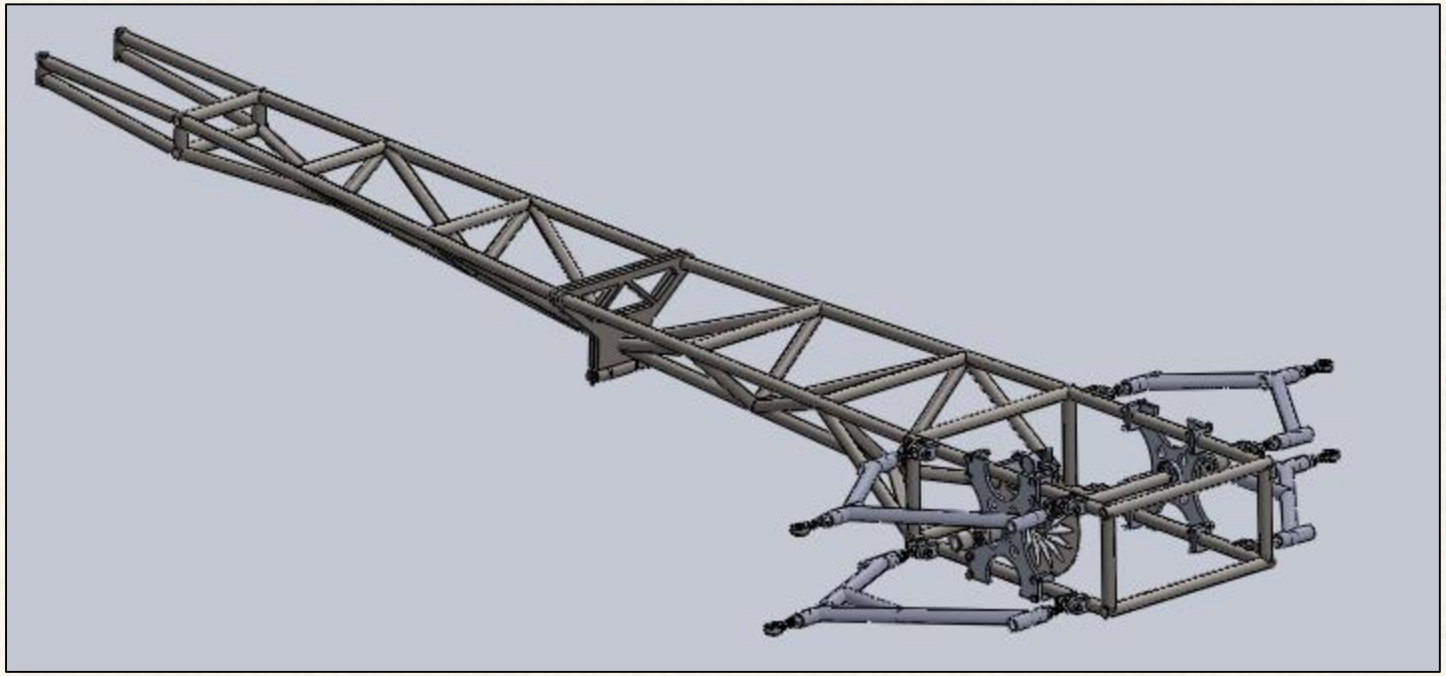


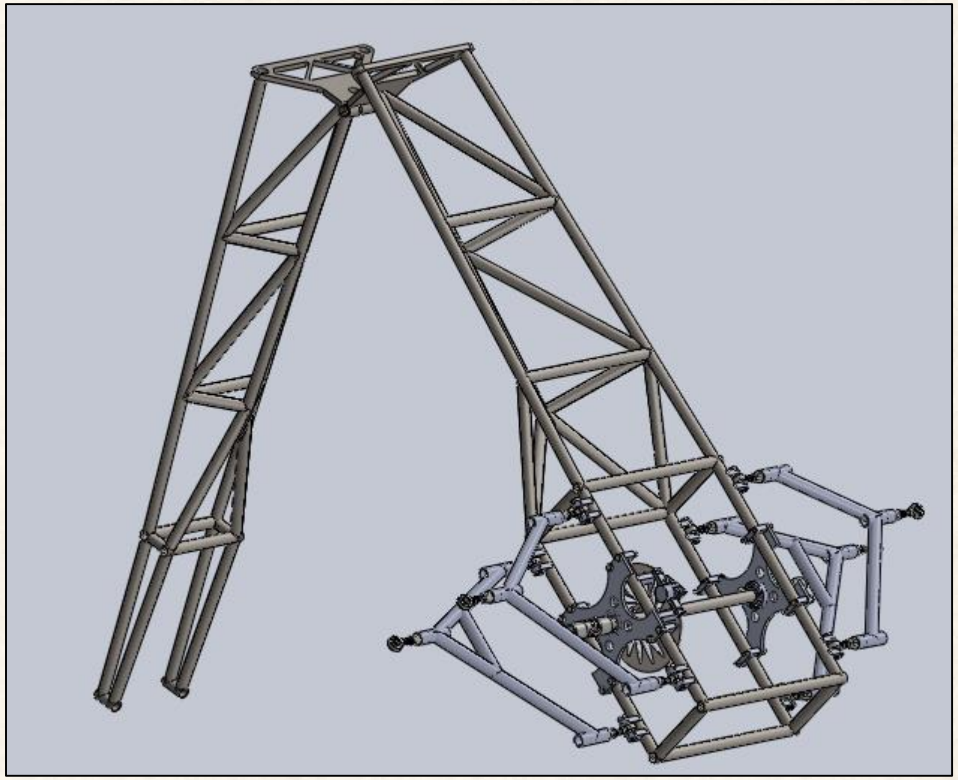
Figure 33: Current Drivetrain Assembly

- **Designed around bike components (brake calipers, conical bearings, sprockets)**

- Driveshaft : 0.75” OD Mild Steel
  - 2’ section **$11.95**
- Mounting Plates and brackets:
  - 0.25” AL 7075 (selected for weight and strength)
  - 12x24” **$92.85**
- Universal Joints: **$82.80**

Assembly





Figures 34-35: Current Drivetrain Assembly

Rear Drive Train

- Back-to-back configuration means rear wheel is driven in reverse direction of pedaling motion.
- Challenge is to reverse chain direction while maintaining coplanar chain line.

Figures 36-38: Rear Drivetrain

Future Plans

Steering Assembly

- Steering wheel, hand levers
- Two-wheel or all-wheel steering

Design of wheels

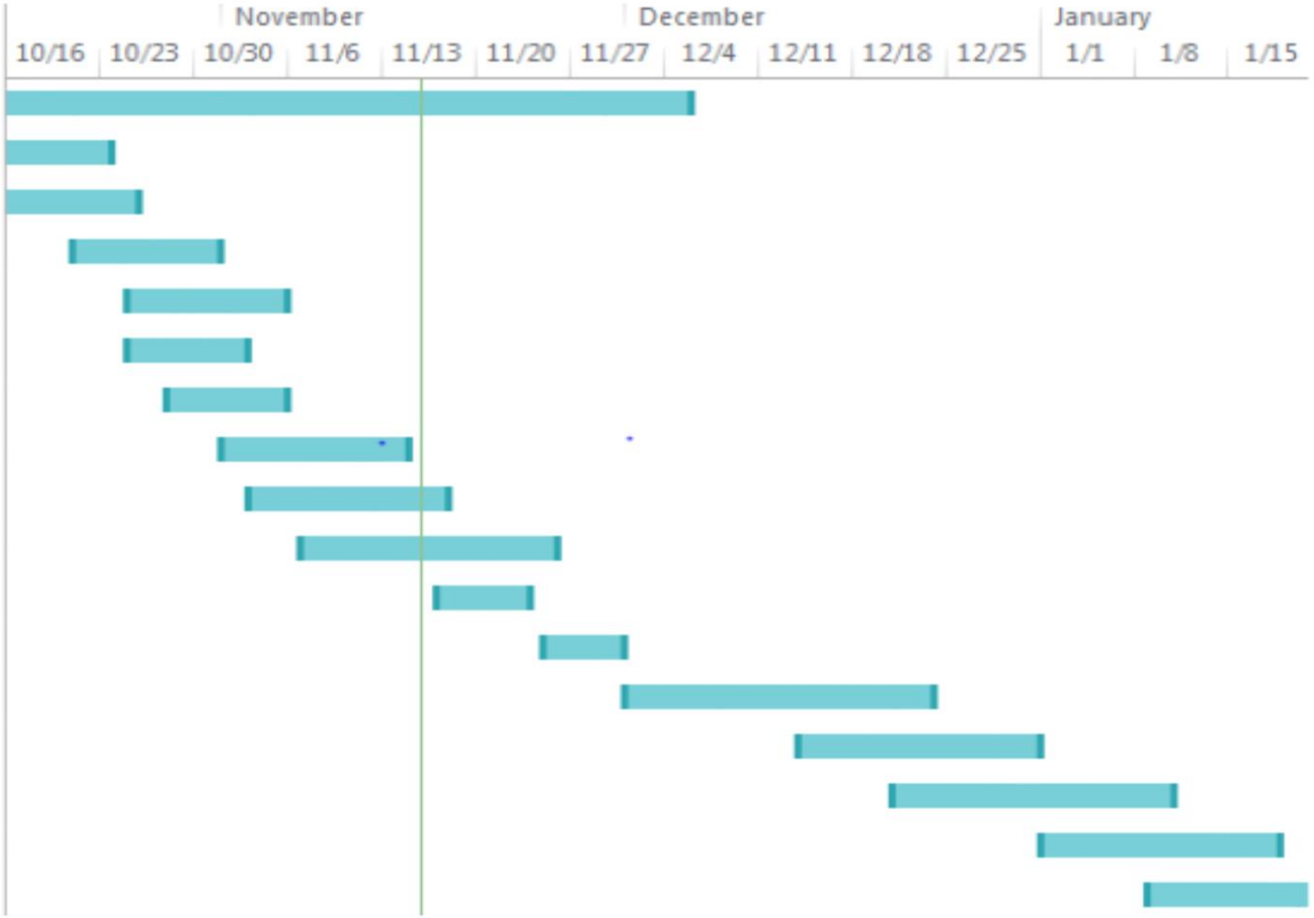
- Materials, size, shape, tread

Seats Assembly

- Seat belts
- Backing
- Adjustability
- Mounting

Gantt Chart

Task Name	Duration	Start	Finish
Fundraising	47 days	Sat 10/1/16	Mon 12/5/16
Conceptual Design	17 days	Sat 10/1/16	Sun 10/23/16
Chassis	11 days	Tue 10/11/16	Tue 10/25/16
Part Selection	7 days	Fri 10/21/16	Mon 10/31/16
Drivetrain	10 days	Tue 10/25/16	Sat 11/5/16
Suspension	7 days	Tue 10/25/16	Wed 11/2/16
Steering	7 days	Fri 10/28/16	Sat 11/5/16
Purchasing	10 days	Tue 11/1/16	Mon 11/14/16
Wheels	11 days	Thu 11/3/16	Thu 11/17/16
Manufacturing	15 days	Mon 11/7/16	Fri 11/25/16
Brakes	5 days	Thu 11/17/16	Wed 11/23/16
Revisiting Design	4 days	Fri 11/25/16	Wed 11/30/16
Finalize Design	17 days	Thu 12/1/16	Fri 12/23/16
Refine Reports	14 days	Wed 12/14/16	Sat 12/31/16
Continue Manufacturing	15 days	Wed 12/21/16	Tue 1/10/17
Tweek Design	14 days	Sun 1/1/17	Wed 1/18/17
Testing	17 days	Mon 1/9/17	Tue 1/31/17



Acknowledgements

Thank you to these places for parts:

- University Cycles
- Great Bicycle Shop
- Joe’s Bike Shop

Thank you to the student machine shop for information on designing for manufacturing.

Thank you to SAE for advice on vehicular design.

Thank you to Dr. Shih and Dr. Gupta for design advice and project management.

References

http://portfolios.risd.edu/gallery/23181693/RISD-DTC-Moon-Buggy-Parts for a arms

https://grabcad.com/library for basic parts

McMaster Carr

Intro and suspension