NFPA Fluid Power VEHICLE Challenge

NFPA Education and Technology Foundation

FINAL PRESENTATION
Western Michigan University
Advisors: Alamgir Choudhury & Jorge Rodriguez
DATE: April 11, 2019

Introductions

- Team Members: Nathan Browder, Zac Hall, Van B. Lal, David Maawma, & Hayden Staub
- Advisors: Dr. Alamgir Choudhury, & Dr. Jorge Rodriguez
- Mentor: Thomas Finsel

Team with Mentor

Presentation Overview

- Problem statement and objective
- Design objectives
- Vehicle design
- Fluid power circuit
- Selection of hardware
- Results and incorporation of analyses
- Vehicle construction
- Vehicle testing
- Lesson learned

Problem Statement and Objectives

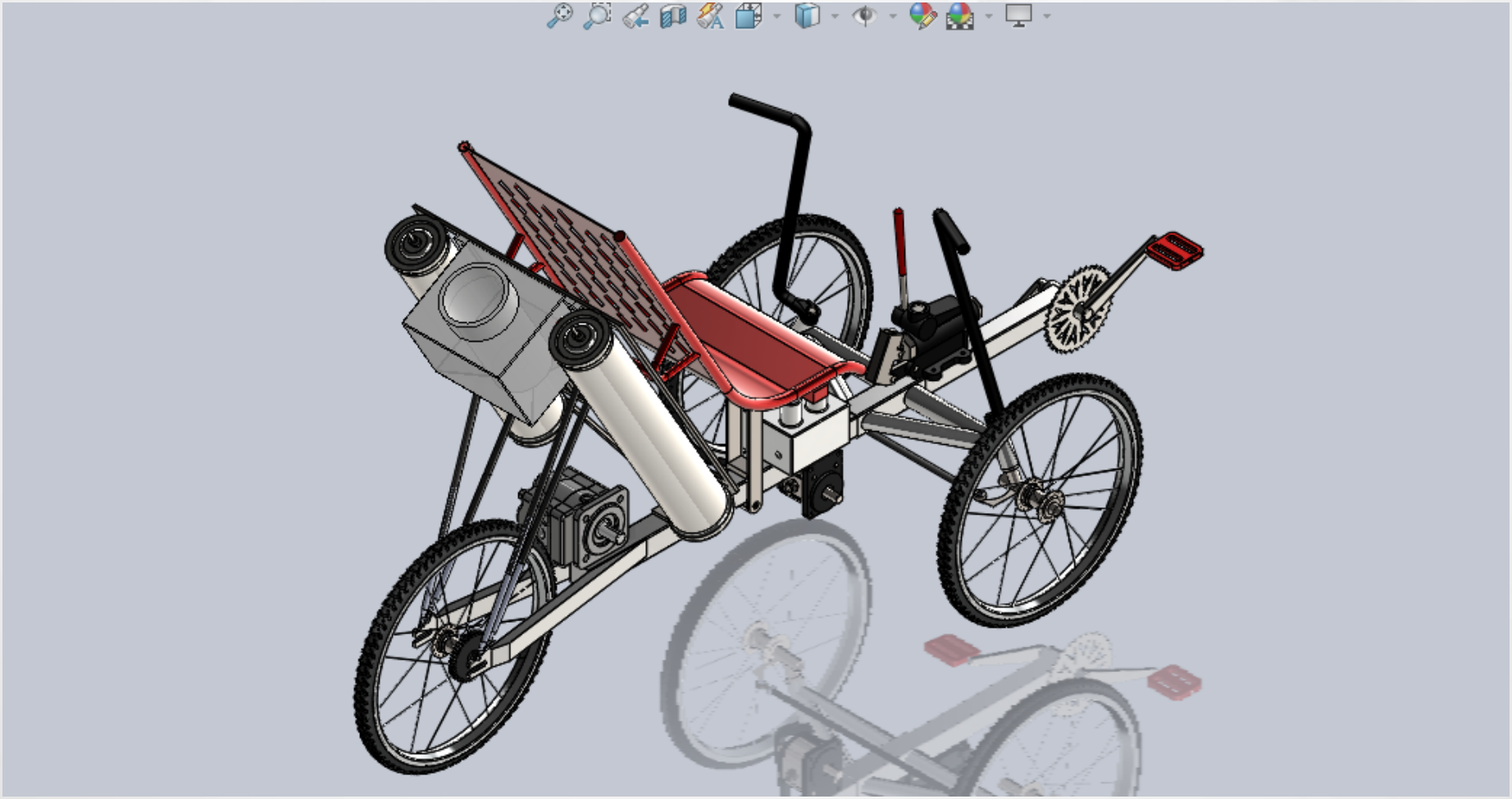
- Design and build a manually operated vehicle through hydraulic power
- Meet all rules and safety regulations set by NFPA:
  - Operated independently by single rider
  - Independent braking system
  - Able to store and utilize hydraulic energy
  - Vehicle weight under 210 lbs.

Concept Selection

Table 1. Frame design selection matrix

Category	1-10	Modified Recumbent Trike		Ellipitical Bike		Standing Scooter Vehicle		Rowing Vehicle	
	Weight	1-10	Point	1-10	Point	1-10	Point	1-10	Point
Safety	10	7	70	4	40	1	10	10	100
Weight	9	4	36	7	63	10	90	1	9
Efficiency	9	7	63	10	90	1	9	4	36
Stability	8	10	80	4	32	1	8	7	56
Manufacturability	8	10	80	4	32	1	8	7	56
Maneuverability	7	7	49	1	7	4	28	10	70
Operatability	7	10	70	7	49	1	7	4	28
Innovation	6	1	6	4	24	10	60	7	42
Maintanence	5	7	35	4	20	1	5	10	50
Drag	4	7	28	1	4	4	16	10	40
Assembly	4	10	40	4	16	1	4	7	28
Ergonomic	3	10	30	7	21	1	3	4	12
Cost	2	7	14	1	2	10	20	4	8
Aesthetics	1	1	1	7	7	10	10	4	4
		Total Point:	602	Total Point:	407	Total Point:	278	Total Point:	539

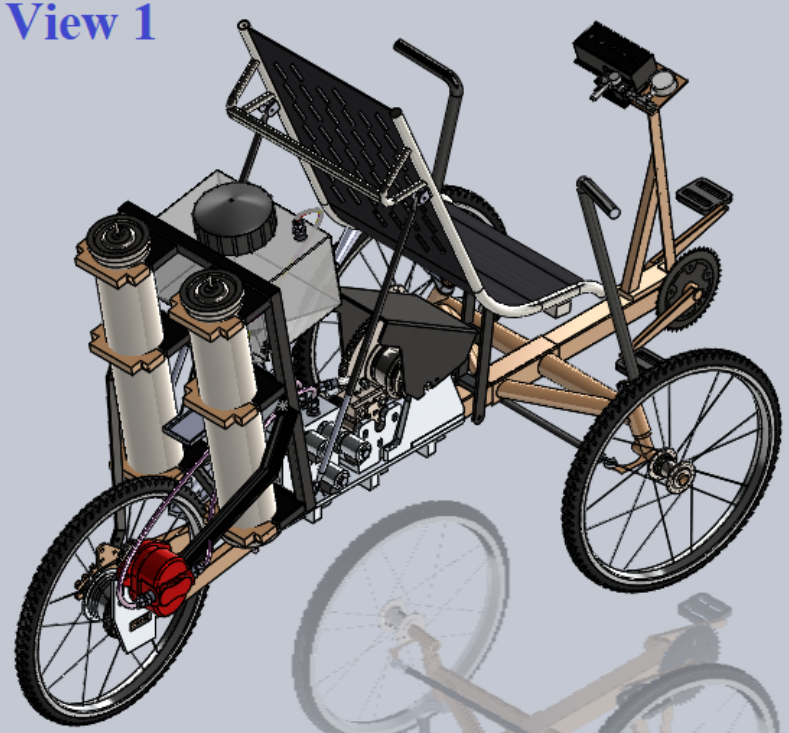
Vehicle Design Midway Review



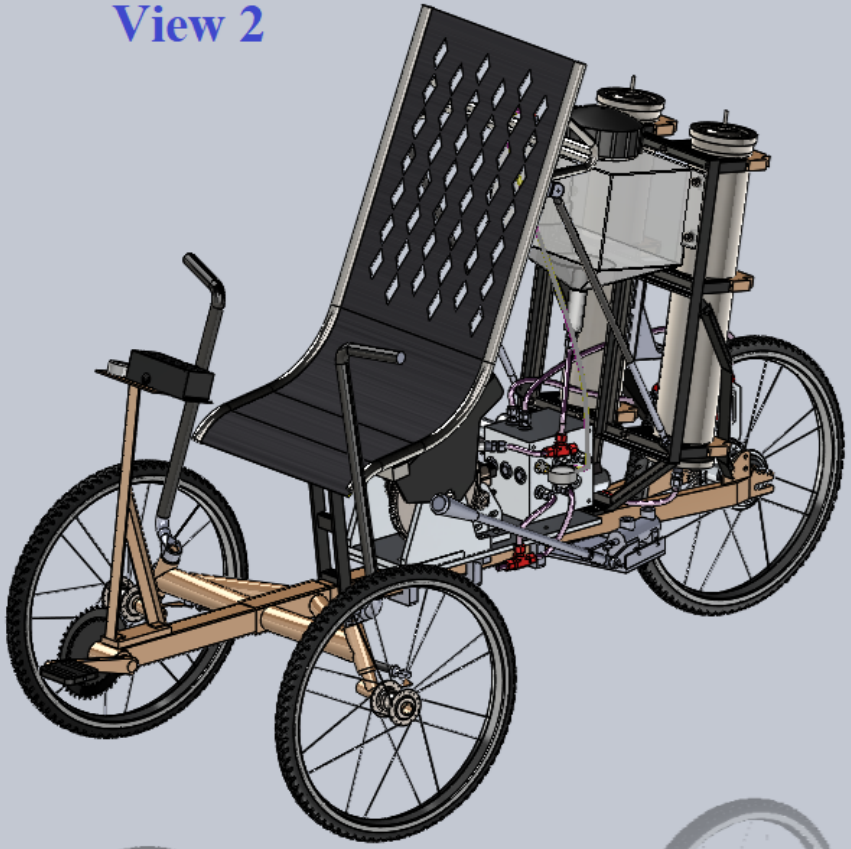
CAD model in SolidWorks

Vehicle CAD Design after Midway Review

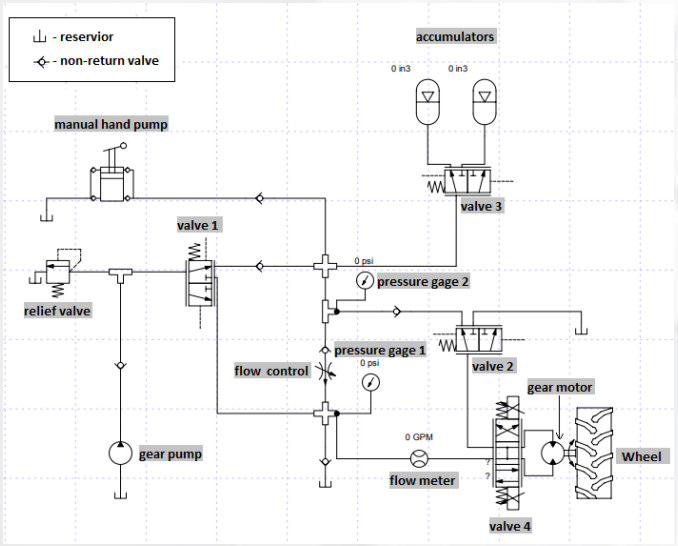
View 1



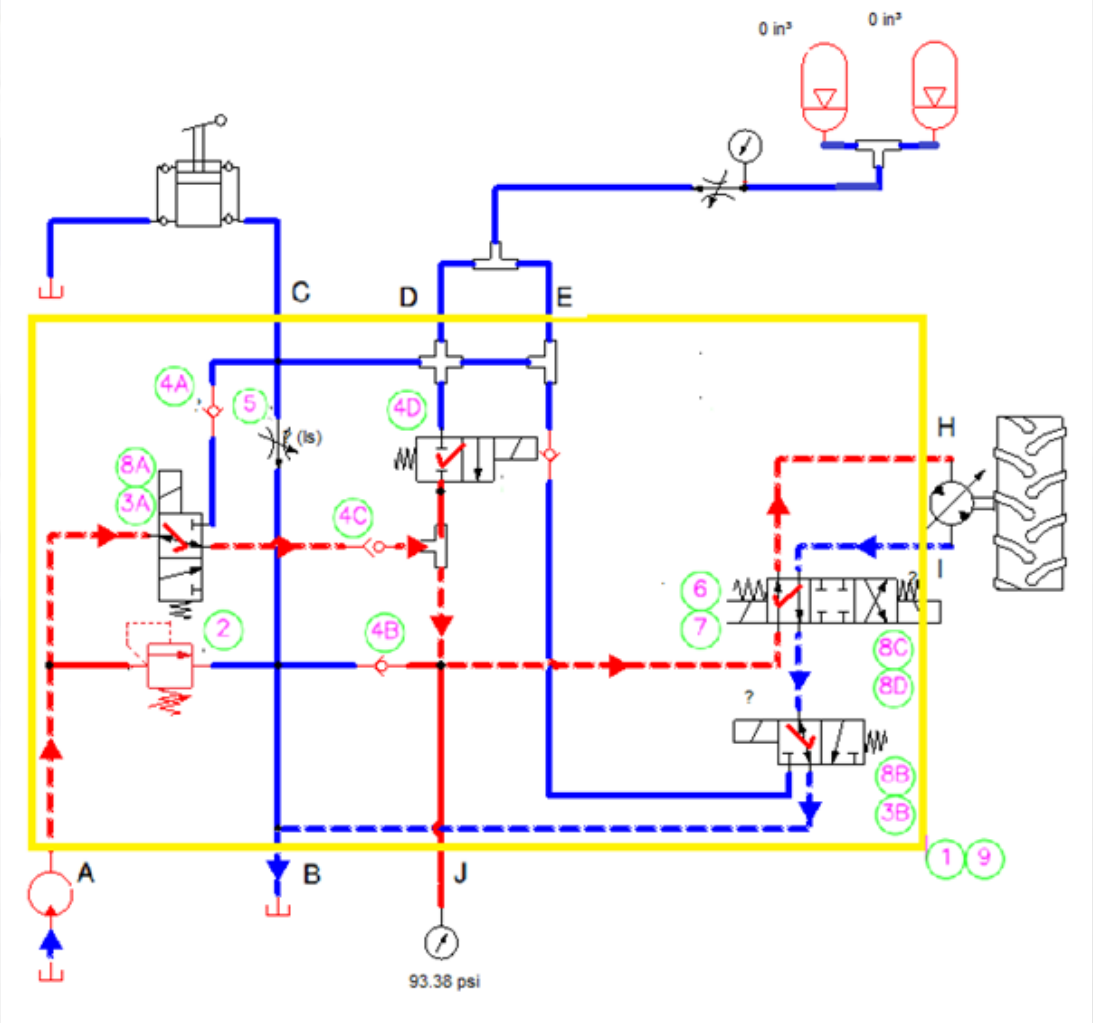
View 2



Hydraulic Circuit:
Old and Updated Version



Old Circuit



Updated Circuit

Midway Review Component List

- Pump 0.40 CID keyed Shaft
- Motor 0.54 CID, keyed shaft 0.625’’ bi-rotation
- Two 1 gallon accumulators
- Hand pump
- Manifold

Pump Selection after Midway Review

Table 2. Pump selection matrix

	(1 - 10)	Steeering Pump		Eaton Pump	
Category	Weight	(1- 10)	Point	(1- 10)	Point
Weight	10	9	90	4	40
Efficiency	9	8	72	8	72
cost	3	5	15	10	30
system Complexity	5	8	40	6	30
Dimension	8	9	72	5	40
			289		*212*

Selected pump: **Steering Pump**

- Light weight
- Better operation at low RPM

Finalized Accumulator Selection after Midway

Table 3. Accumulator selection matrix

Accumulator	Gallon	Weight (lb)	lb/gal
A1PT31003	0.12	6	50.00
A1QT3100-3	0.25	10	40.00
A13100-3	1.00	32	32.00
A1.53100-3	1.50	41	27.33
T0BUL4.5AL-20	1.08	20	18.52

TOBUL4.5AL selected because lowest “weight to volume ratio”

Summary of Midway Calculations

- Line sizing 5/16 in. diameter
- Motor gear to wheel ratio: 1 to 0.27
- Peddle to pump ratio: 1 to 15
- Needed torque 101.95 lb.in.
- Estimated horsepower 0.58 hp
- Estimated wind resistance 0.1hp

Updated Calculation Summary after Midway Review

- Track grade 3%
- Load 380 lbs.
- Estimated torque required 129.14 lb-in

Gear Ratio:

Pedal to pump:	Highest ratio	1 to 24.2
	Lowest ratio	1 to 7.91
Motor to wheel:	Highest ratio	1 to 0.70
	Lowest ratio	1 to 0.13

Vehicle Construction

- Obtained necessary building materials from around twelve different suppliers based off CAD model
- Aluminum, steel, paint, nuts, bolts, screws, sprockets, hydraulic hoses and connections, brake cables, wires, and battery
- Total project cost $1457.58

Vehicle Construction

Many components came off previous WMU hydraulic bikes and from hydraulics lab

- 14 speed internal gear hub to motor and an 8 speed internal gear hub to go to pump.
- Two accumulators
- Four gear shifters wire and housings
- Screws, bolts and nuts
- Gears and sprockets

Vehicle Construction

Welding, drilling, grinding, painting, cutting, milling, and general machining was done in the WMU student lab and machine shop.

Assembly and building took place in the WMU fluids lab.

3D printed plastic components printed in house.

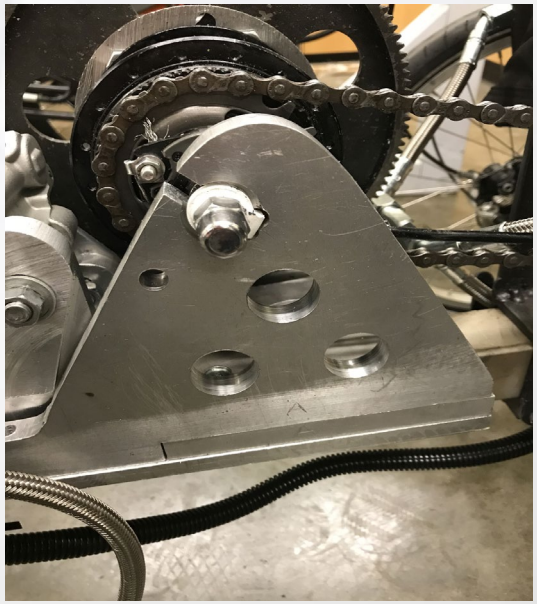
Valves, Ports and Connections

- 2.5 gallon reservoir (1)
- Braided stainless steel line (25ft)
- Solenoid valves (5)
- Needle valve (1)
- T fitting (2)
- Pressure gauge (2)
- Rubber hose (13in)

Vehicle Construction

Vehicle Construction

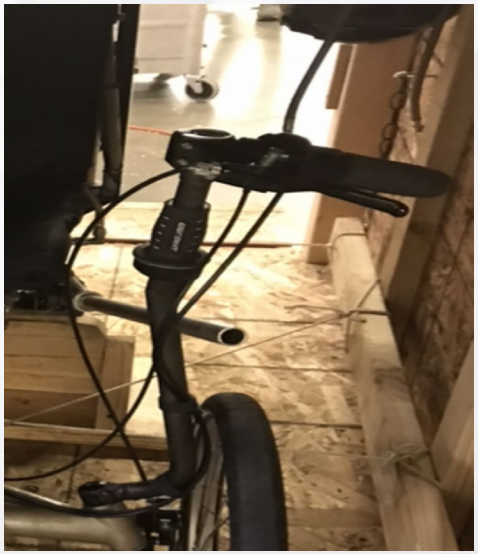
- Roughly 20 aluminum brackets fabricated
- Designed for alignment and adjustability for gears
- Strong enough to safely secure all components



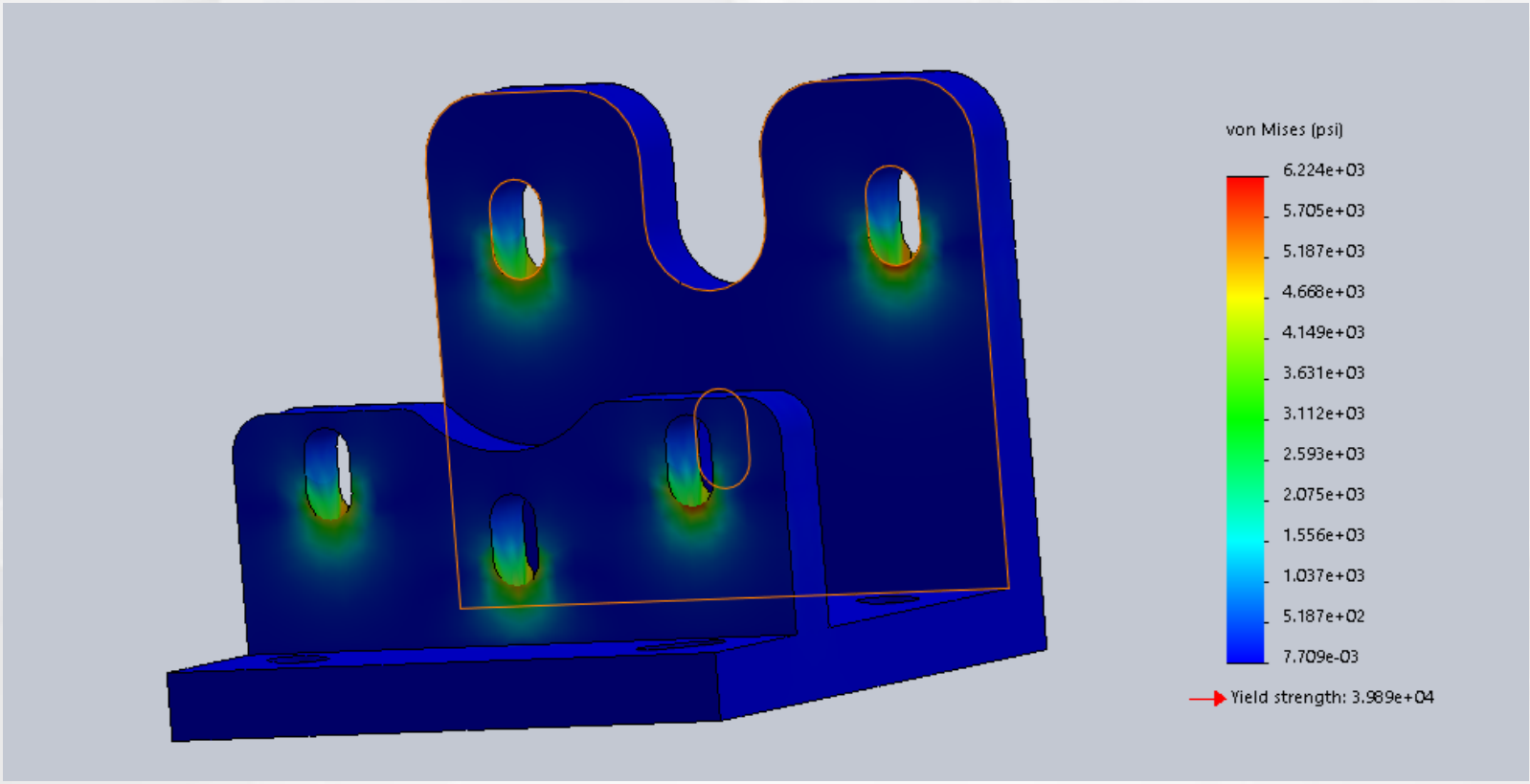
Vehicle Construction

Modifications Made to Bike

- Seat raised to allow room for peddling and components
- Handlebars raised and flared out
- Four gear shifters modified to vehicle needs
- Modifications made to pedal sprockets and gear hubs
- Power steering pump pulley removal and and shaft key-way created



Finite Element Analysis



Pump bracket

Bracket for pump support will not fail at stress above operating condition

Vehicle Testing

Overall the vehicle operated well in terms of gear train alignment and vehicle structure

Video Link https://www.youtube.com/watch?v=gLt1yRZhwis

Testing with Mentor

- First working test of manifold and hydraulic circuit and electric circuit
- Direct drive, accumulator change, accumulator discharge, and reverse working
- Regenerative braking ideas where brain stormed
- Gearing alignment and shifting was successful

Vehicle Testing

Problems Discovered Though Testing

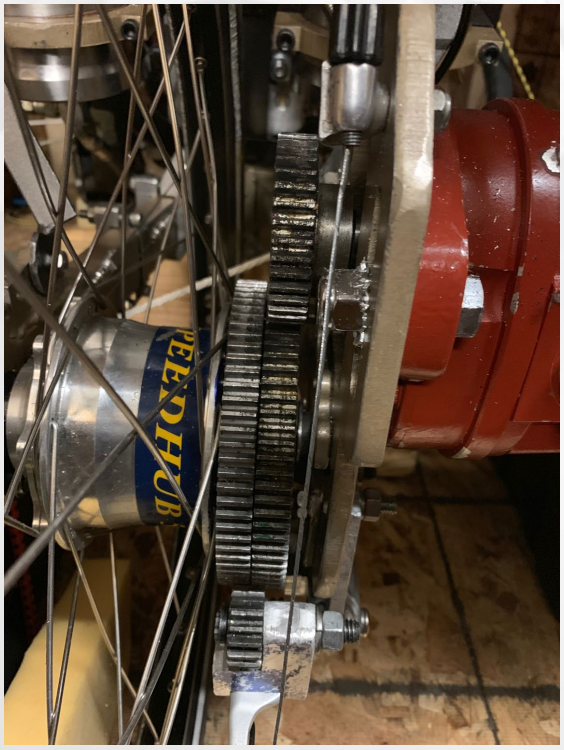
- Squeaking in pump at high pressures
- Battery dying after short time of use
- Regenerative energy recovery not working as well as intended
- Harder to pedal uphill than expected
- Feet slide off pedals
- Need a longer bar for hand pump
- Vehicle was very close to max weight at 200lbs

Adjustments and Revisions

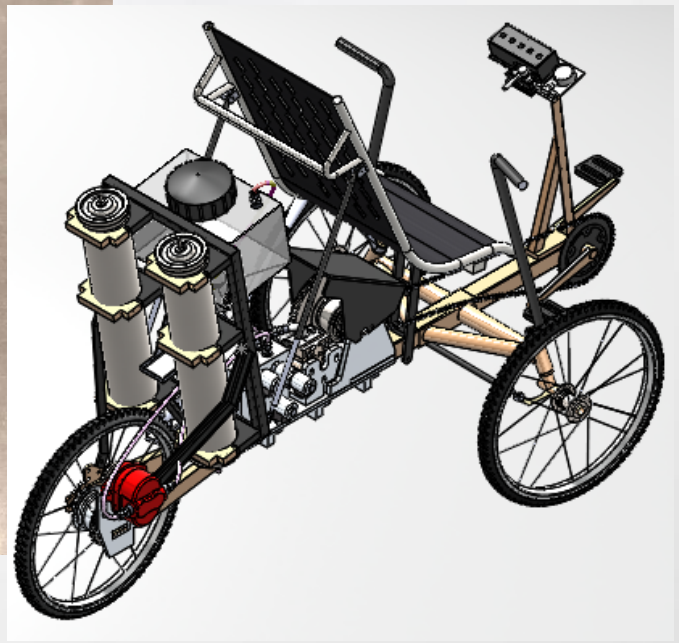
- Painted parts
- Cleaned up wiring
- Created new rack system from aluminum instead of steel to saving 6.1 lbs.
- Extended hand pump handle

Adjustments and Revisions

- Attached gear train for regenerative braking
- Straps added to pedals for feet



Final Vehicle



Lessons Learned

- Design the hydraulic circuit to be in direct drive when valves not energized
- Start fabrication a month earlier
- Understand and get failure with major hydraulic components before designing

Special Thanks!

Senior design teacher: Dr. Aller

Team advisors: Dr. Choudhury, Dr. Rodriguez

Team mentor: Tom Finsel

Machine shop: Jonathan Gallee (FSAE)

NFPA: Stephanie Scaccianoce, Lynn Beyer

Depatie Fluid Power Co: Hydraulic Hose Donation