NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation
The University of Akron
Advisor: Dr. Scott Sawyer
4/11/2019

Meet the Team

Members

- Steve Gluck (Mentor), Wayne Ritchie, Madison Graham, Emily Dicks, Ariana Cupello

About Us

- All seniors in Mechanical Engineering
- Graduating in May of 2019
- New to Fluid Power Designs

Problem Statement

- Compete in Fluid Power Vehicle Challenge
  - Sprint Race: 600 feet
  - Efficiency Race: Travel maximum distance using pressurized accumulator (from a stop)
  - Endurance Race: Approximately 1 mile time trial

Summary of Midway Presentation

- Design Objectives
- Fluid Power Circuit Design
- Hardware Selection
- Analysis using FEA

Objectives

Design Goals

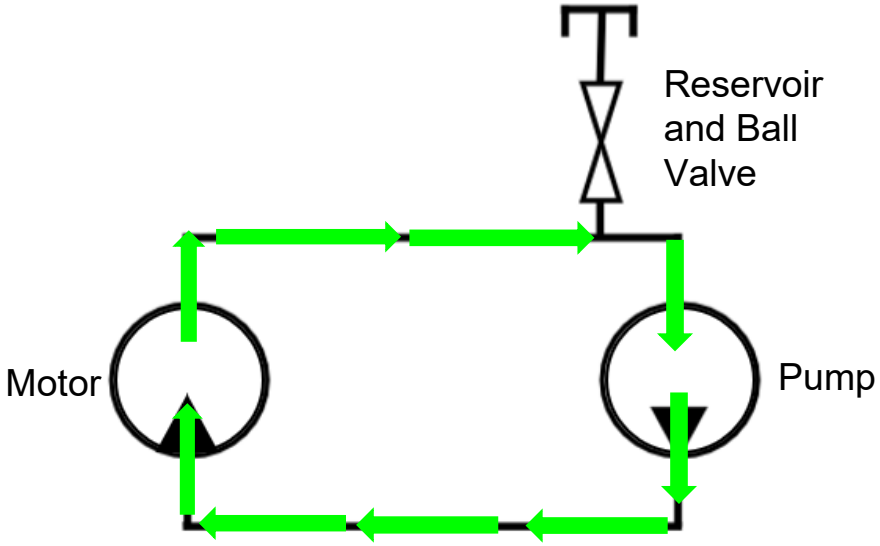
- Dual Front Wheels for Stability
  - Efficiency Challenge
- Optimize Gear Ratios
  - Endurance Challenge
- Dual Drive/Regeneration Circuits

Design Outcomes

- Stabilizer Wheels
  - Component Attachment
- Direct Mesh on Drive Side
  - Optimized Gear Ratios
  - Back Wheel Gear Hub
- Dual Drive/Regeneration Circuits
  - Run Simultaneously
- Rider Comfort
  - Improved Valve Locations
  - New Seat

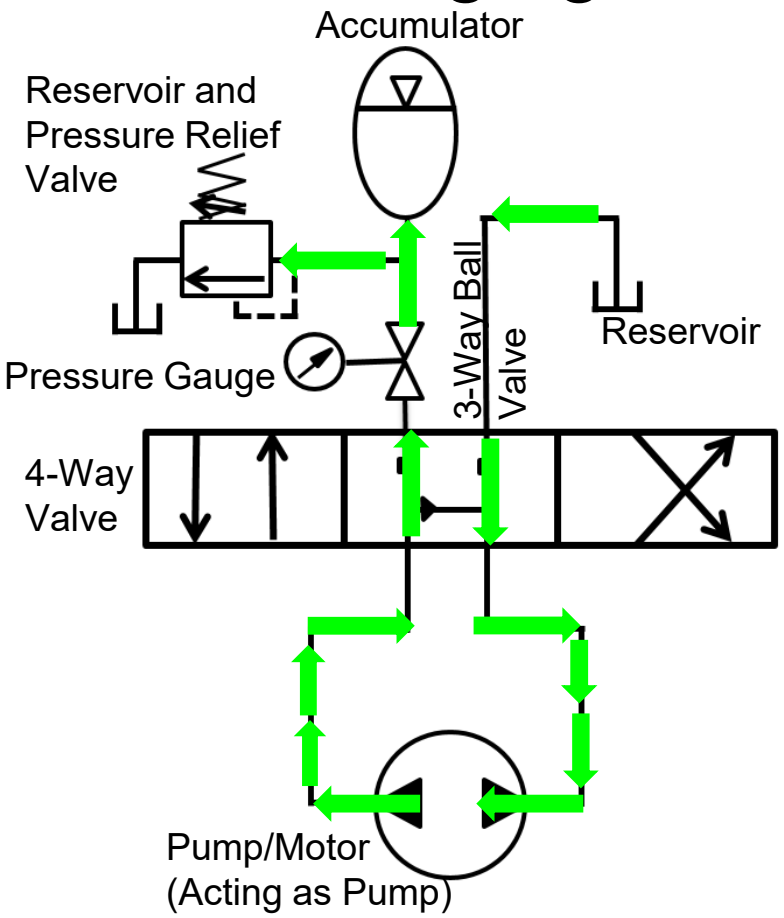
Fluid Circuit Design

Pump Circuit - Powered by Pedal Input

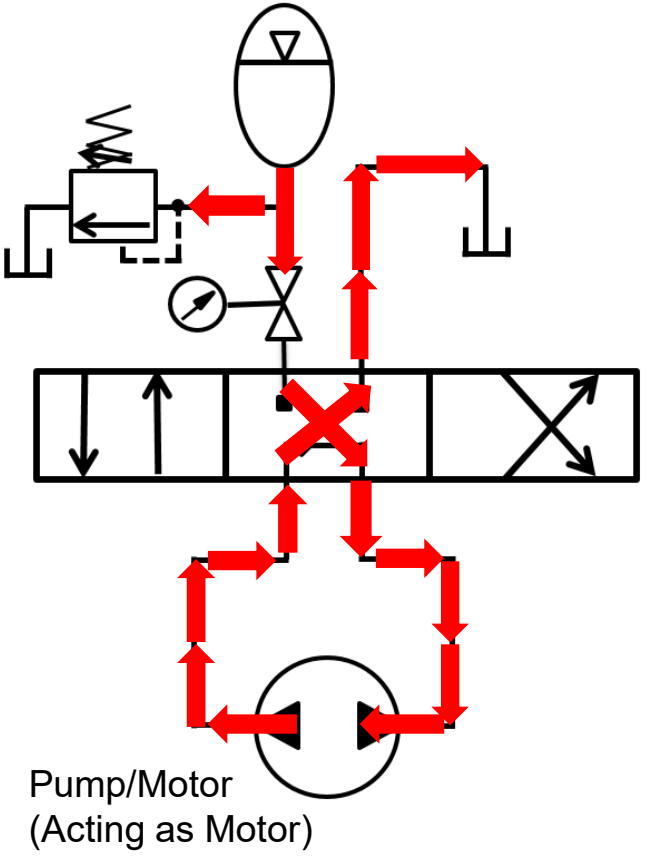


Fluid Circuit Design

Accumulation Circuit Charging



Accumulation Circuit Discharging



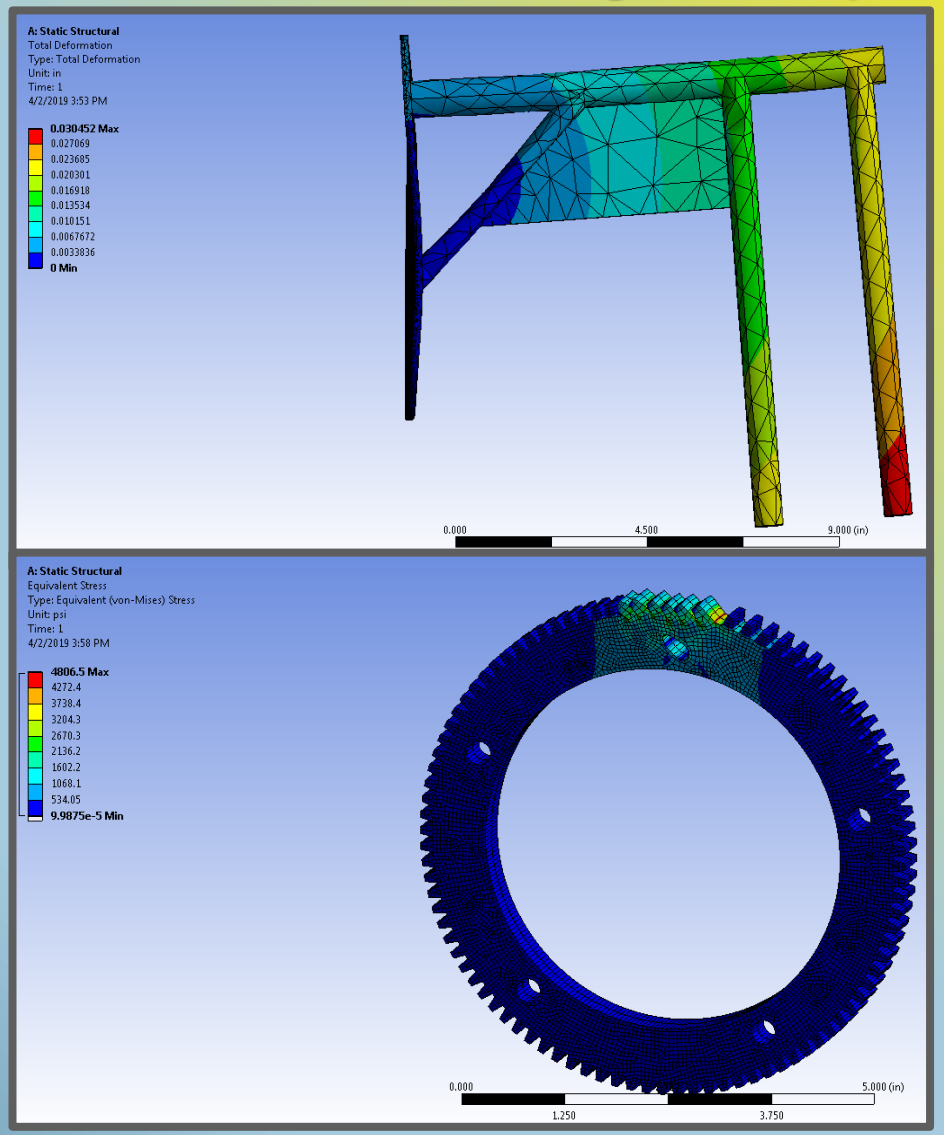
Hardware Selection

- **Pedal Circuit**
  - Eaton 26002 RZC Pump
    - 0.5 CIR
  - Eaton 26 Series Motor
    - 0.54 CIR

- **Accumulation Circuit**
  - 1 Pint Accumulator
    - Precharge pressure = 0.9*1500 = 1350 psi
  - 5000 psi Pressure Relief Valve
  - Parker F11-5 Motor
  - Eaton 4-Way Valve

Analysis Using FEA

Variable		Units
Pump CIR	0.5	in3/rev
Motor CIR	0.537	in3/rev
Tube Diameter	0.25	in
Cross-Sectional Area	0.0003408846195	ft2
Input Gear Ratio	3.428571429	
Radius of Tire	13.5	in
Weight (Bike and Rider)	200	ibf
Peddling Speed	70	rpm
Pump RPM	240	
Pump GPM	0.5194805195	
Pump Volumetric Flow	0.001157403804	ft3/sec
Fluid Velocity	3.395294883	ft/sec
Pressure Change per rev.	25.97956242	ibf/in2
Motor RPM	223.4636872	
Tire RPM (Assuming no losses)	156.424581	rpm
Bike Speed	12.56477509	mph
System Pressure	1600.00	psi
Pump rpm	240.00	rpm
Hydraulic Power	361.30	Watts
Torque of Pump	127.3239545	ibf-in
Input Power	361.5535658	Watts



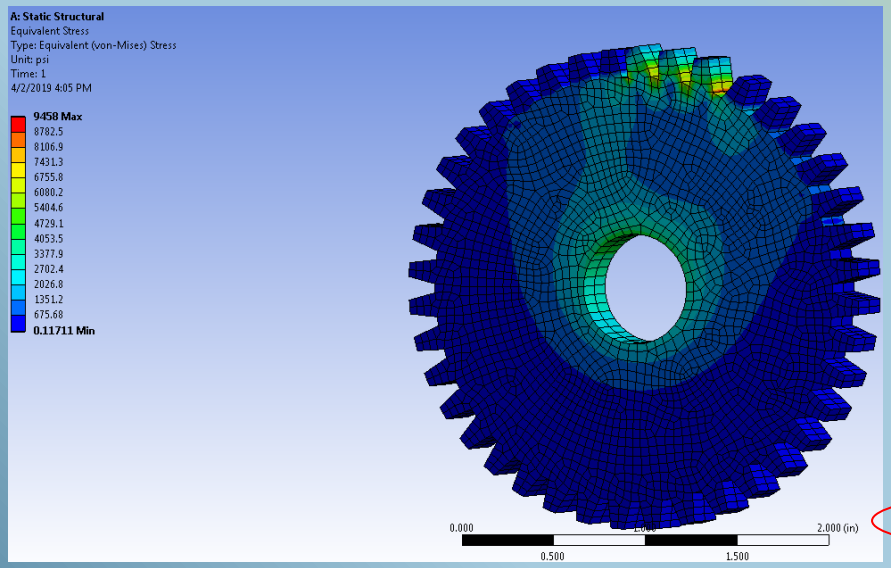
Tangential Load on a Gear

Wt=Torque/radius

Overall Load

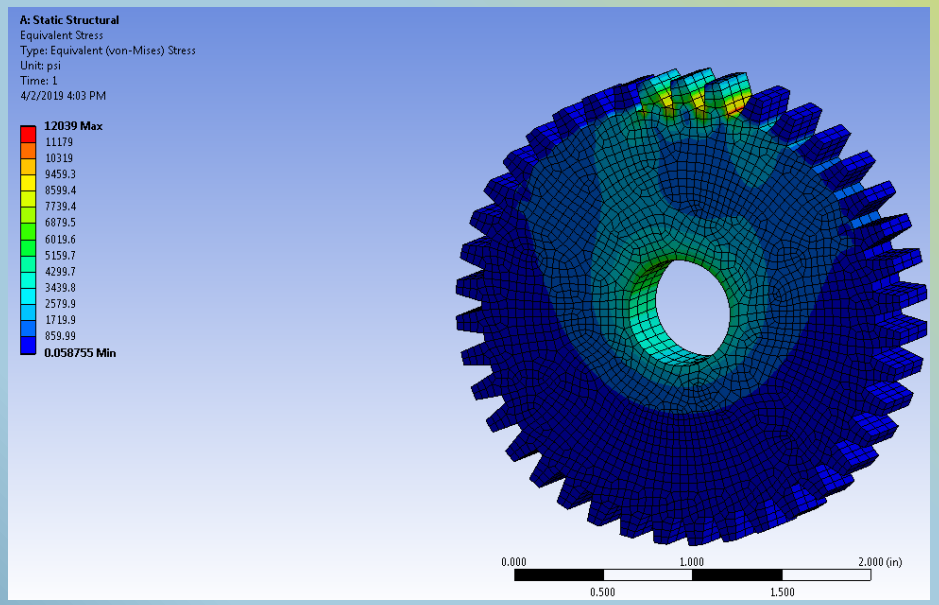
W=Wt/cos(phi)

Analysis Using FEA



Accumulation Side Charging		
System Pressure	2000	psi
CIR of Motor	0.3	in3/rev
CIR of Pump	0.3	in3/rev
Desired CIR	0.4027207623	in3/rev
Tire RPM (Assuming No Losses)	156.424581	rpm
Pump RPM	125.1396648	rpm
Pump GPM	0.1625190452	gpm
Volumetric Flow	0.0003620928103	ft3/sec
Fluid Velocity	1.062215159	ft/sec
Rolling Resistance Torque	128.19	ibf-in

Discharge		
System Pressure	2500	psi
Fluid Velocity (assuming no losses)	33.30669862	ft/sec
Volumetric Flow	0.01135374129	ft3/sec
Motor GPM	5.095928837	gpm
Motor RPM	3923.865204	rpm
Torque of Motor	119.3662073	p*CIR
Torque of Motor_C	119.3831169	p*gpm*36.77/rpm
Torque Applied to Wheel	149.2288961	ibf-in
Desired Gear Ratio	1.25	
Fluid Power		HP
Power of Motor		Watts
Power of Motor		HP
Rolling Resistance Torque	128.19	ibf-in
Total Torque	277.4188961	lbf-in



Vehicle Construction

- Disassembling previous bike

- Manufacturing Plate and Bars
  - Cardboard Cutout
  - Spacing With Washers
  - 3D Printed Spacers

Vehicle Construction

- Design/Build Reservoir
  - Calculated volume of fluid needed
  - Transparent design to monitor amount of fluid being used
  - Two iterations to adjust length

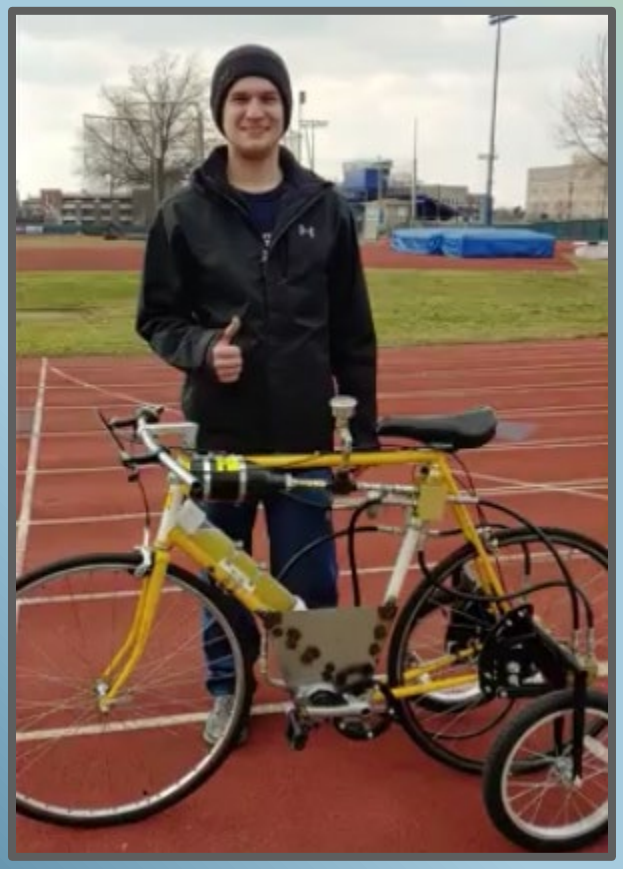
Vehicle Construction

- Stabilizer Wheels
  - Supports pumps on back wheel
  - Prevents tipping/falling

- Finishing Touches
  - Handlebars/Grips
  - Painting
  - Grind away excess bolts
  - Replace zip ties

Vehicle Testing

NFPA Fluid Power Vehicle Challenge

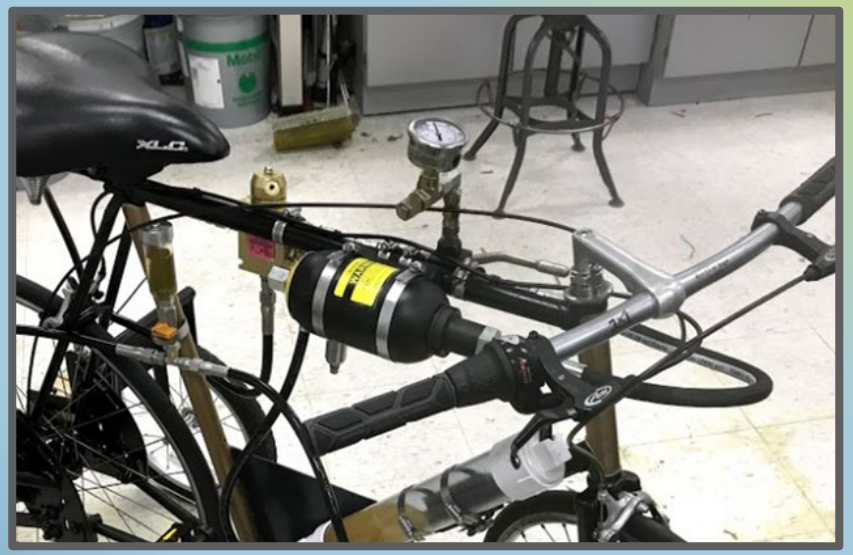


Vehicle Testing

Team Member	Sprint (100m)	Efficiency	Details	Endurance (1 mi)	Details
Ariana	N/A	N/A		N/A	Bike was too large
Emily	40 s	90 ft	No-precharge (2500 starting psi)	8 mins 15 sec	Not charging
		453 ft	1350 psi pre-charge	9 mins 47 sec	Charging Intermittently
Madison	35 s	105 ft	No-precharge (2500 starting psi)	7 mins 45 sec	Not Charging
		500 ft	1350 psi pre-charge	7 mins 35 sec	Charging Intermittently
Wayne	28 s	92 ft	No-precharge (2500 starting psi)	7 mins 1 sec	Not Charging
		492 ft	1350 psi pre-charge	7 mins 7 sec	Charging Intermittently

Testing and Improvements

- Precharge for endurance must be lowered
  - ~500psi
- Rearranging components
  - Remove rubbing points
  - Viewing pressure gauge (proper orientation)
  - Improve overall balance
- Wheel axis bent
  - True the wheel



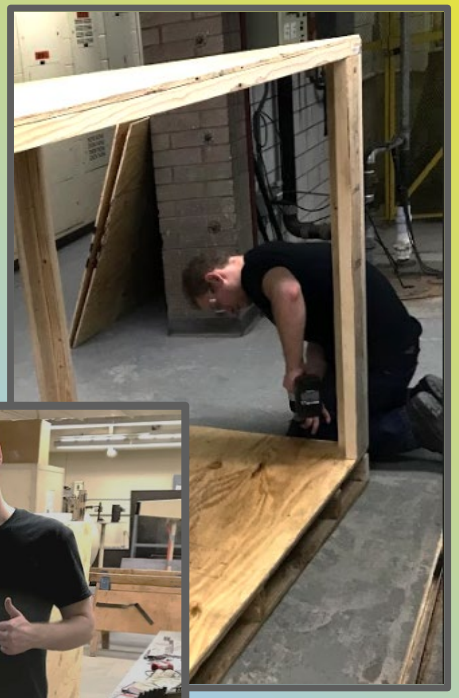
Cost Analysis

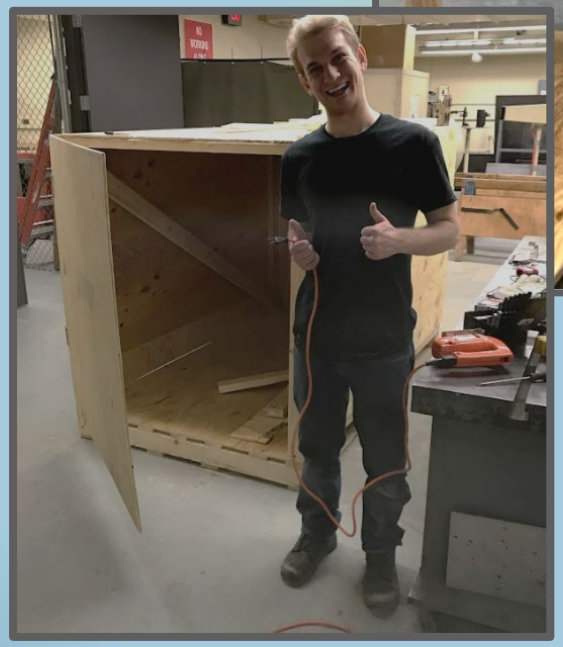
Bicycle Components		Quantity	Unit Cost	Cost	New/Upcycled
Bike Parts	Centurion Semi Pro Bike	1	250.00	250.00	Upcycled
	Handle Bar Assembly	1	85.00	85.00	Upcycled
	Innova 2304 Tire	2	30.39	60.78	Upcycled
	Steel Bike Rim	2	39.99	79.98	Upcycled
	Rear Shimano Alfine 8 SPD Hub	1	235.00	235.00	Upcycled
	8 SPD Shift Kit	1	14.15	14.15	Upcycled
	Bike Pedals	1	12.99	12.99	New
	Handle Bar Grips	1	9.99	9.99	New
	Brake Assembly	2	14.00	28.00	Upcycled
	Bike Rear Wheel Kit	1	160.96	160.96	New
	Brake Levers	1	19.00	19.00	Upcycled
Hydraulic Components					
Pumps/Motors/Gears	Eaton 26002-RZC	1	314.50	314.50	Upcycled
	Eaton 26 Series Motor	1	480.00	480.00	Upcycled
	Parker F11-5 Motor	1	475.00	475.00	Upcycled
	Accumulator	1	667.00	667.00	New
	Eaton Vickers 3 Position 4 Way Valve	1	205.50	205.50	Upcycled
	Martin Hub Gears-S1050	1	133.26	133.26	Upcycled
	Martin Hub Gears-S1628BS	1	43.35	43.35	Upcycled
	Martin Sprocket Gear-S1696	1	111.01	111.01	Upcycled
Connectors	Ball Valve	1	51.43	51.43	New
	Pressure Gauge	1	30.22	30.22	New
	Relief Valve	1	21.60	21.60	New
	Clear Fluid Reservior Kit	1	57.75	57.75	Upcycled
	#10 SAE/ORB Male x 3/8" NPTF Female	2	2.51	5.02	Upcycled
	3/8" JIC Male x 3/8" NPTF Male	4	0.78	3.12	New
	3/8" JIC Male x 3/8" JIC Female 45°	2	2.91	5.82	New
	3/8" JIC Female x 1/4" JIC Male	2	5.37	10.74	New
	1/4" JIC Male x 1/4" JIC Male x 1/4" NPTF Male	1	2.66	2.66	Upcycled
	3/8" NPTF Male x 1/4" NPTF Female	1	0.97	0.97	New
	1/2" NPTF Male x 3/8" NPTF Female	2	1.20	2.40	Upcycled
	3/8" NPTF Male x 1/4" NPTF Male	1	1.12	1.12	New
	3/8" JIC Male x #12 SAE/ORB Male	3	3.06	9.18	New
	3/8" JIC Female x 3/8" JIC Female	4	5.14	20.56	Upcycled
	3/8" JIC x #6 SAE/ORB Male	3	1.57	4.71	New
	#6 SAE/ORB Female x 3/8" NPTF Male	1	2.70	2.70	Upcycled
	3/8" JIC Male x 3/8" JIC Female Swivel 90°	1	2.24	2.24	New
	3/8" JIC Male x 3/8" JIC Male x 3/8" NPTF Female	1	6.45	6.45	Upcycled
	3/8" JIC Solid Cap	1	0.80	0.80	Upcycled
	3/8" JIC Female Swivel Branch Tree	1	3.84	3.84	Upcycled
	#6 SAE/ORB Male x 1/4" JIC Male	4	1.29	5.16	New
	#8 SAE/ORB Male x 1/4" JIC Male	2	1.78	3.56	Upcycled
Large Reservoir	3" Pipe Clamp	2	4.97	9.94	New
	1/4x1/4 Adapter	1	3.22	3.22	New
	1-1/2x1/2 PVC Bushing	1	1.78	1.78	New
	2" DMV Cleanout Plug	1	0.98	0.98	New
	2" DMV F Adapter	1	1.67	1.67	New
	2" PVC DMV Hub Cap	1	3.20	3.20	New
	2"x2' PVC Pipe	1	3.98	3.98	New
	1/4x1/8 Hex Bushing	1	1.42	1.42	New
	2"x1-1/2" DMV Reducer	1	1.25	1.25	New
	1/4" to 7/16-20 NPT M	8	8.72	69.76	New
	1/4" 7/16-20 UNF	2	35.82	71.64	New
	1/4" 7/16-20 UNF	2	9.81	19.62	New
		Length ft	$/per foot		
Hosing	Swagelok Hosing	20	4.00	80.00	Donated
Hardware Components					
Bracketing	3/8 Washers	100	0.13	13.00	New
	5/16 Hex nut	5	0.12	0.60	New
	3/8x1-1/2 Hex Bolt	15	0.27	4.05	New
	5/16x1 Hex Bolt	5	0.19	0.95	New
	3/8 Hex Nut	15	0.13	1.95	New
	Low Carbon Steel Plate	1	80.26	80.26	New

Final Vehicle Design

Lessons Learned

- Teamwork makes the dream work
- Focus on safety
- Work with vendors/suppliers
- More documentation
- Shipping process
- Hydraulic application





Thank You

- NFPA
- Parker Hannifin
- Steve Gluck - Team Mentor
- Bob - Wheel and Wrench Bike Shop
- Steve Gerbetz - UA Senior Technician
- Wade Nelson - Welding Master
- Dr. Scott Sawyer - Team Advisor