NFPA Fluid Power VEHICLE Challenge

NFPA Education and Technology Foundation

Final Presentation

Western Michigan University

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Team Advisors: Jorge Rodriguez, Alamgir Choudhury

Industry Mentor: Patrick Petroff

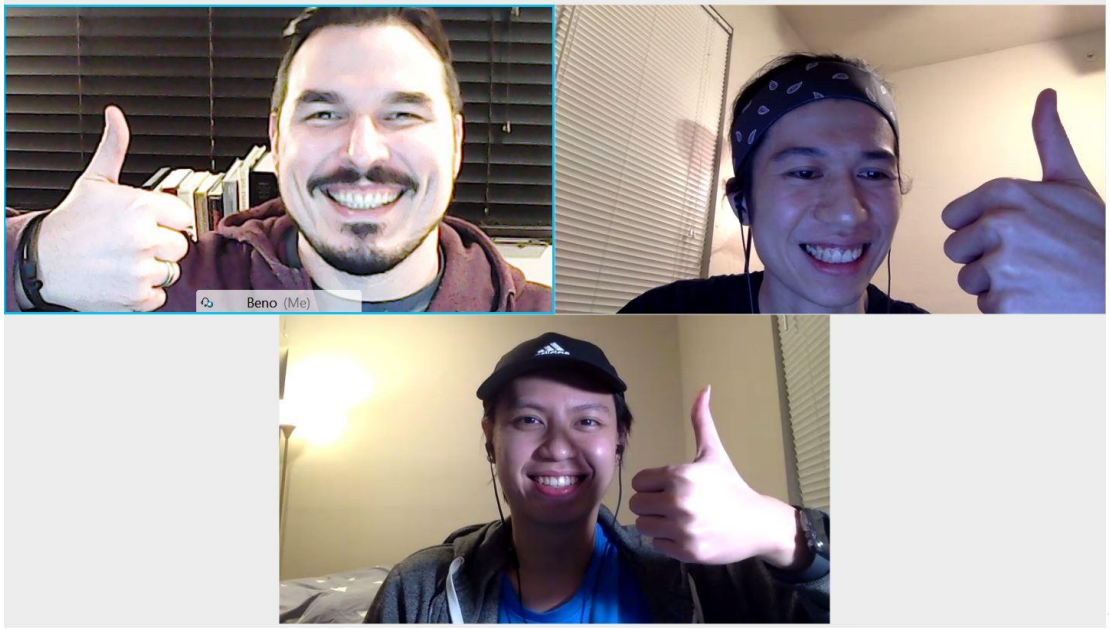
4/9/2021

Western Michigan University

- Fluid Power Vehicle Team

Jared Beno

Hong Yi Lee



Hiew Hang Wan

Agenda

- Design Requirements
- Calculations
- Components
- Hydraulic System
- Electronic System
- Pneumatic System
- The Build
- Testing and Analysis
- Final Product
- Failure Analysis Report
- Lessons Learned

Design Requirements

- Vehicle propels through hydraulics
- Must include pneumatics
- Must include energy storage device
- Maximum total accumulator volume of 1 gallon
- Single rider
- Maximum vehicle weight without rider 210 pounds
- All design must comply with safety policies

Frame

- Recumbent Trike

  (from SunBicycle Tadpole)

Design 1: Upright Tricyle, 3- Wheel
Design 2: Recumbent Tricyle. 3-Wheel
Design 3: Upright Recumbent Bike. 3-Whe
Design 4: One-Wheel Unicycle

Category	1-10	Design 1		Design 2		Design 3		Design 4	
	Weight	1-10	Point	1-10	Point	1-10	Point	1-10	Point
Safety	10	8	80	10	100	7	70	2	20
Efficiency	9	7	63	9	81	8	72	1	9
Stability	9	10	90	10	90	9	81	3	27
Weight	8	4	32	5	40	8	64	3	24
Operability	8	8	64	9	72	7	56	1	8
Maneuverability	7	6	42	7	49	7	49	5	35
Manufacturability	7	8	56	7	49	7	49	1	7
Innovation	6	3	18	6	36	6	36	10	60
Maintenance	5	8	40	7	35	9	45	5	25
Drag	5	3	15	9	45	7	35	4	20
Assembly	4	9	36	8	32	2	8	6	24
Ergonomics	3	7	21	10	30	9	27	5	15
Cost	2	5	10	7	14	5	10	5	10
Aesthetic	1	6	6	7	7	6	6	3	3
		Total Points:	573	Total Points:	680	otal Points:	608	Total Points:	287

Summary of Midway Calculations

- Line sizing : 0.18 in. ID (Pressure Line)

  0.277 in. ID (Suction Line)

- Motor gear to wheel ratio: 1 to 1
- Pedal to Pump Ratio: 1 to 12
- Estimated Torque Needed 86.39 lb.in.
- Estimated Horsepower 0.5 hp
- Estimated Wind Resistance 0.21 hp

Updated Calculations

- Load 286.1 lbs. (including rider)
- Estimated Torque Needed 82.38 lb.in.
- Estimated Horsepower 0.478 hp

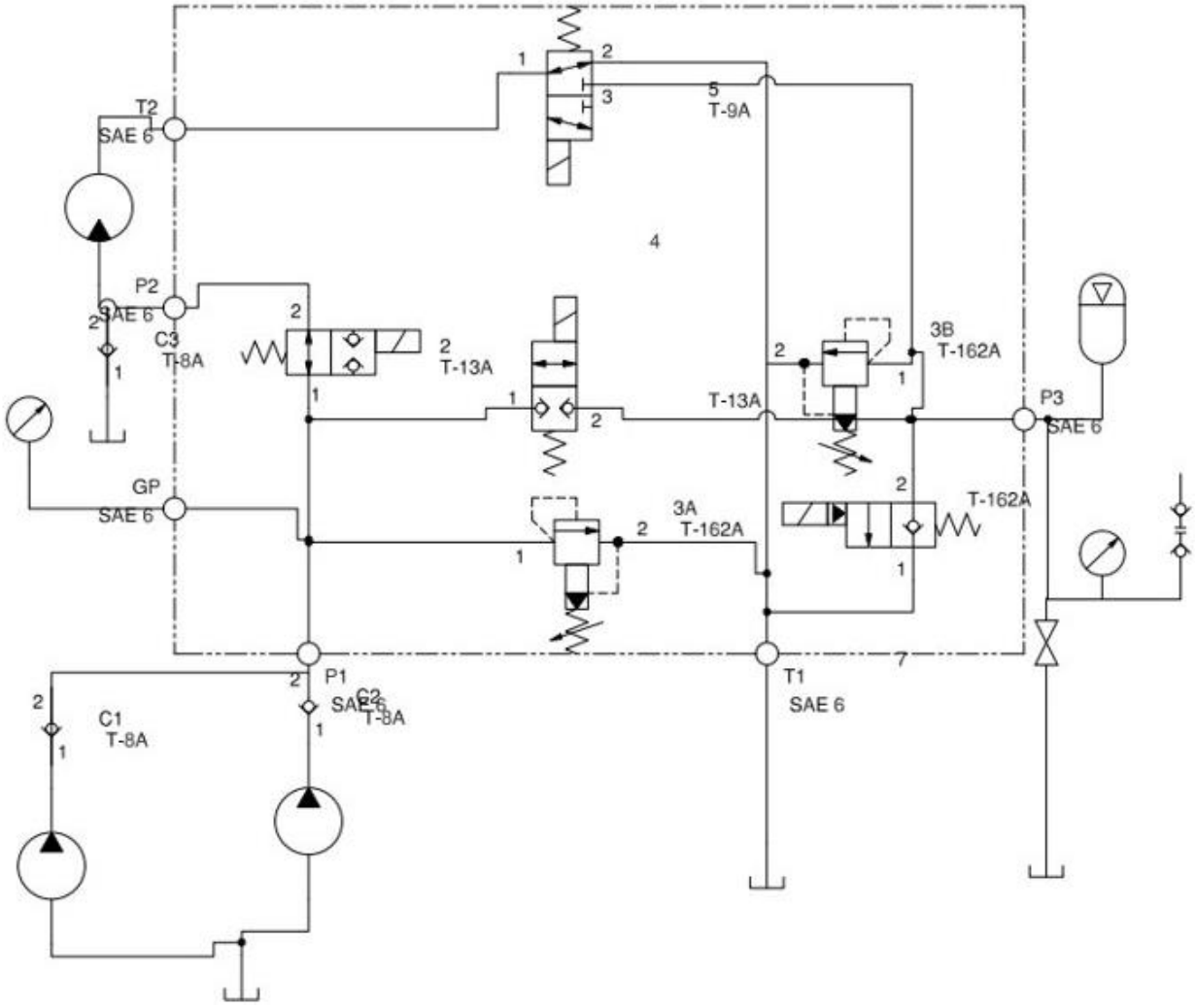
Gear Ratio

Pedal to Pump Ratio: 1 to 26.67

Motor to Wheel Ratio: Highest Ratio 1 to 1.615

Lowest Ratio 1 to 0.527

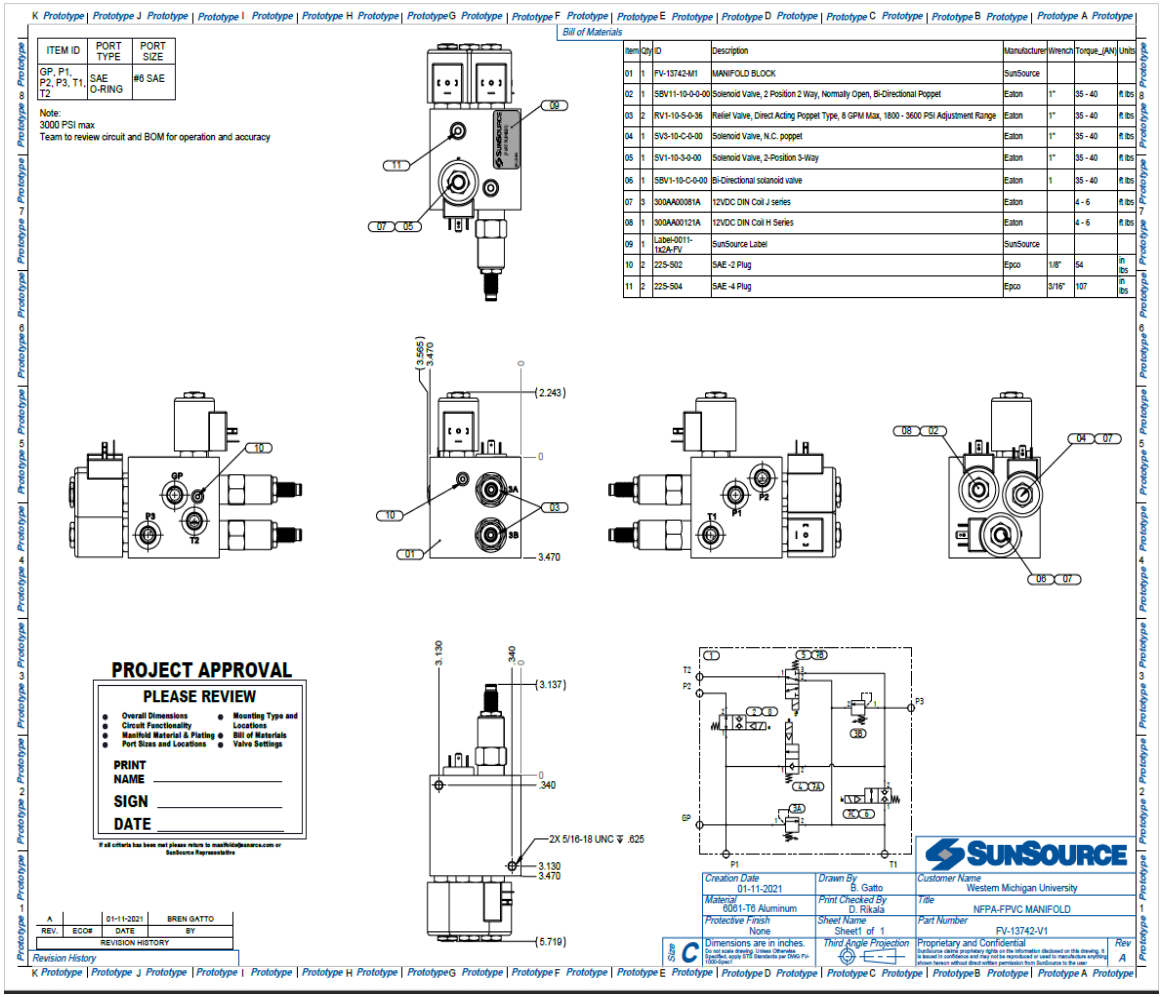
Hydraulic Circuit



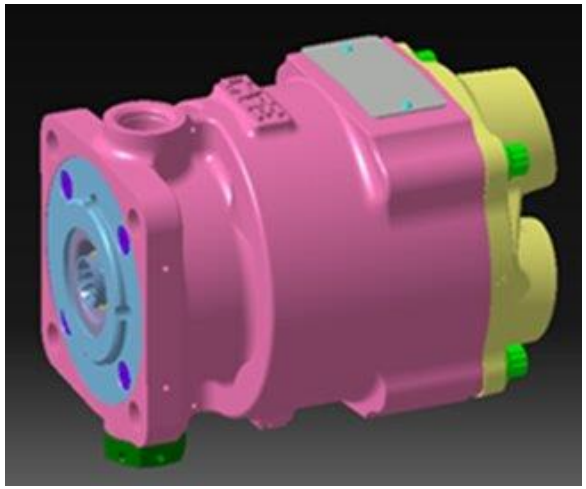
Hardware Selection

- 6061-T6 Aluminum
- High corrosion resistance
- High yield strength

- 41.78 cu in.
- 12 sq in.
- Maximum length 8.86 in.
- Maximum height 5.7 in.
- 12 VDC coils



Hardware Selection

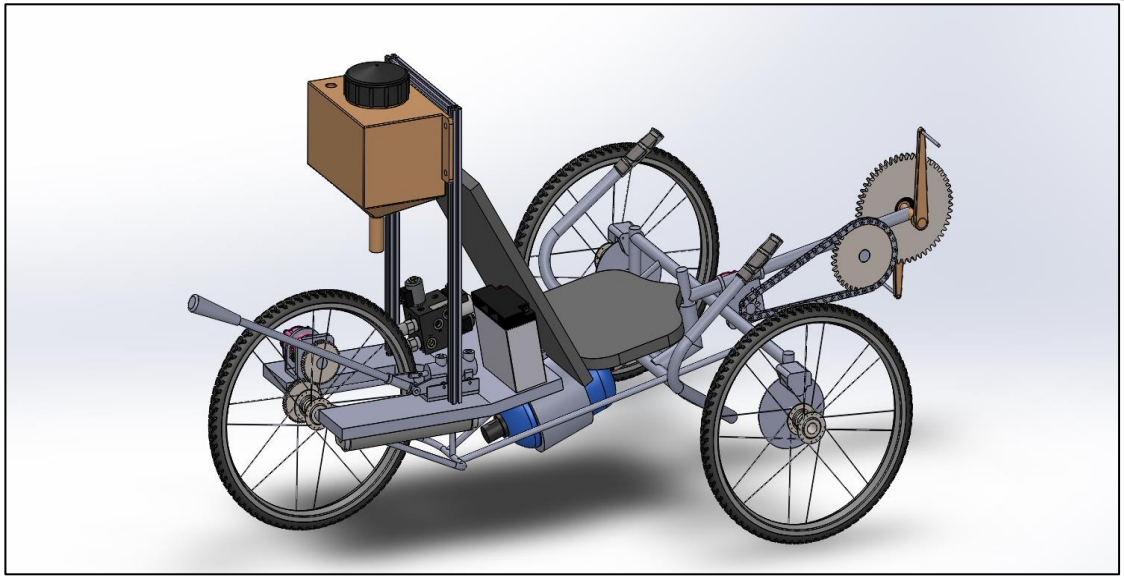


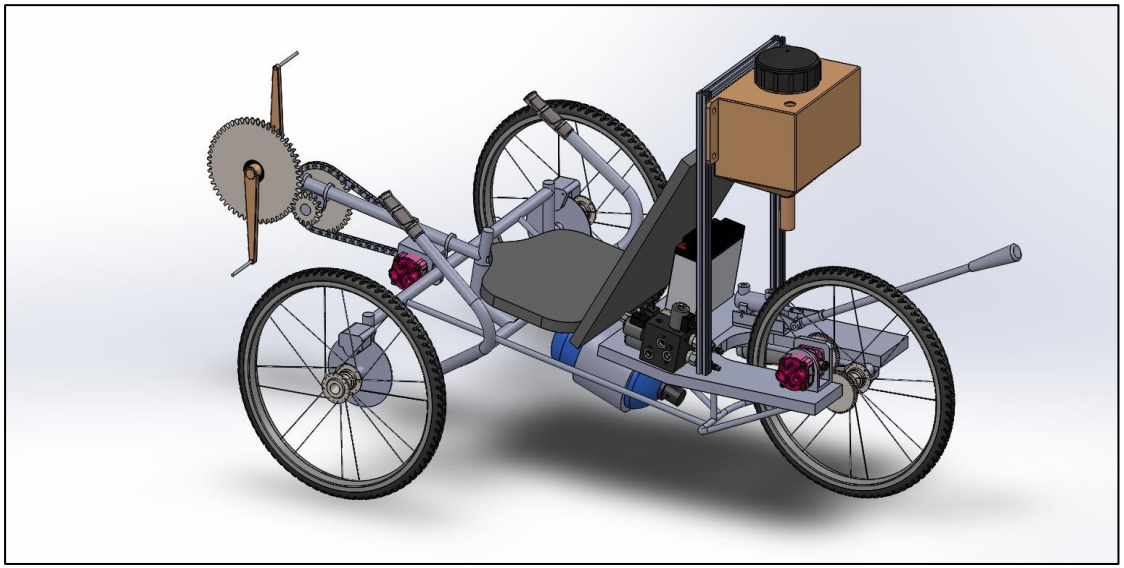
Motor:
– Eaton Gear Motor 26703-DAA
–0.62 CIPR, fixed displacement
–3000 psig
–Bi-rotational, internal drain
–Weight: 7.0 lbs.

Pump:
– Parker Rotary Pump
–0.241 CIPR, fixed displacement
–6600 rpm
–3000 psig
–6.5 gpm
–Weight: 3.44 lbs.

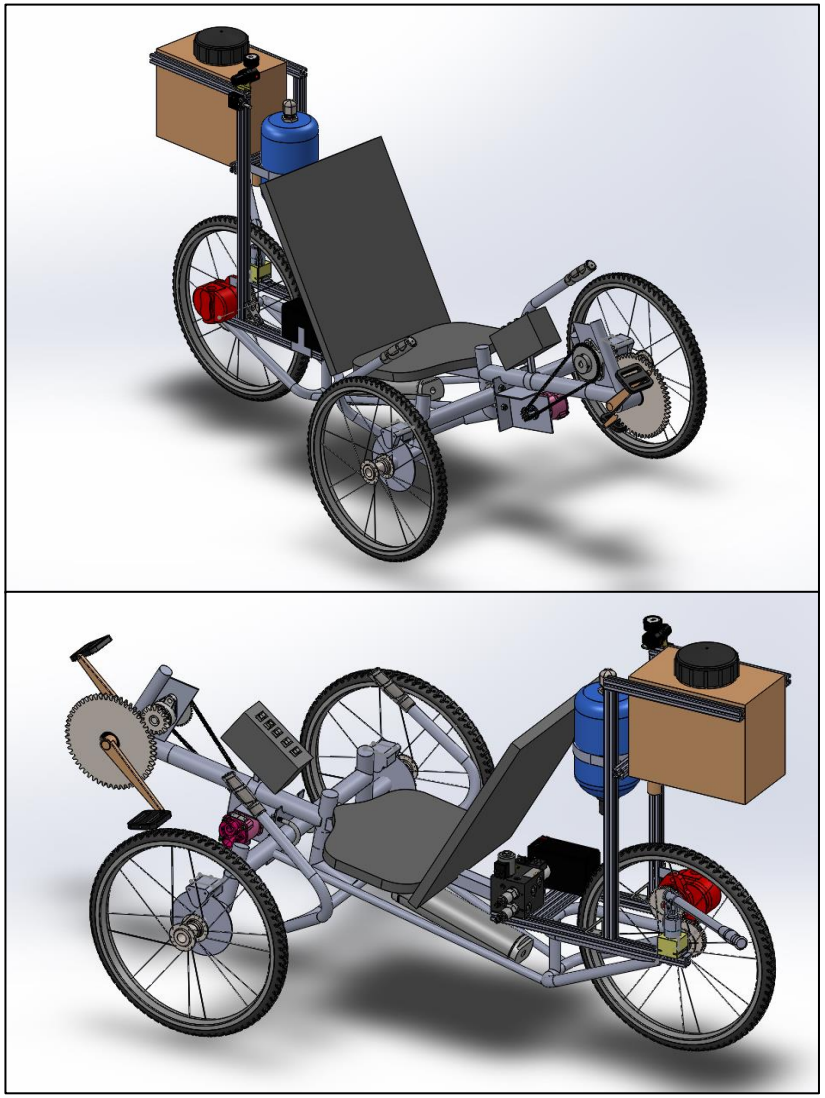
Energy Storage Device:
–1 gallon Steelhead Composite Accumulator

Midway Review Design





Final Design

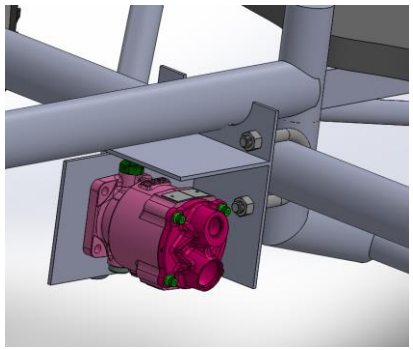


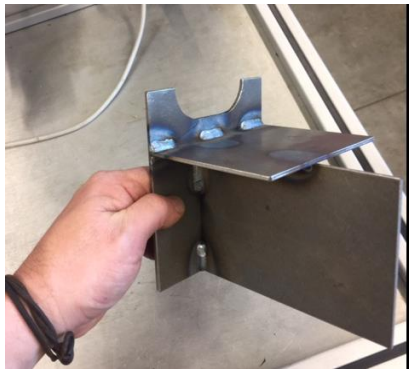
Mounting Platform

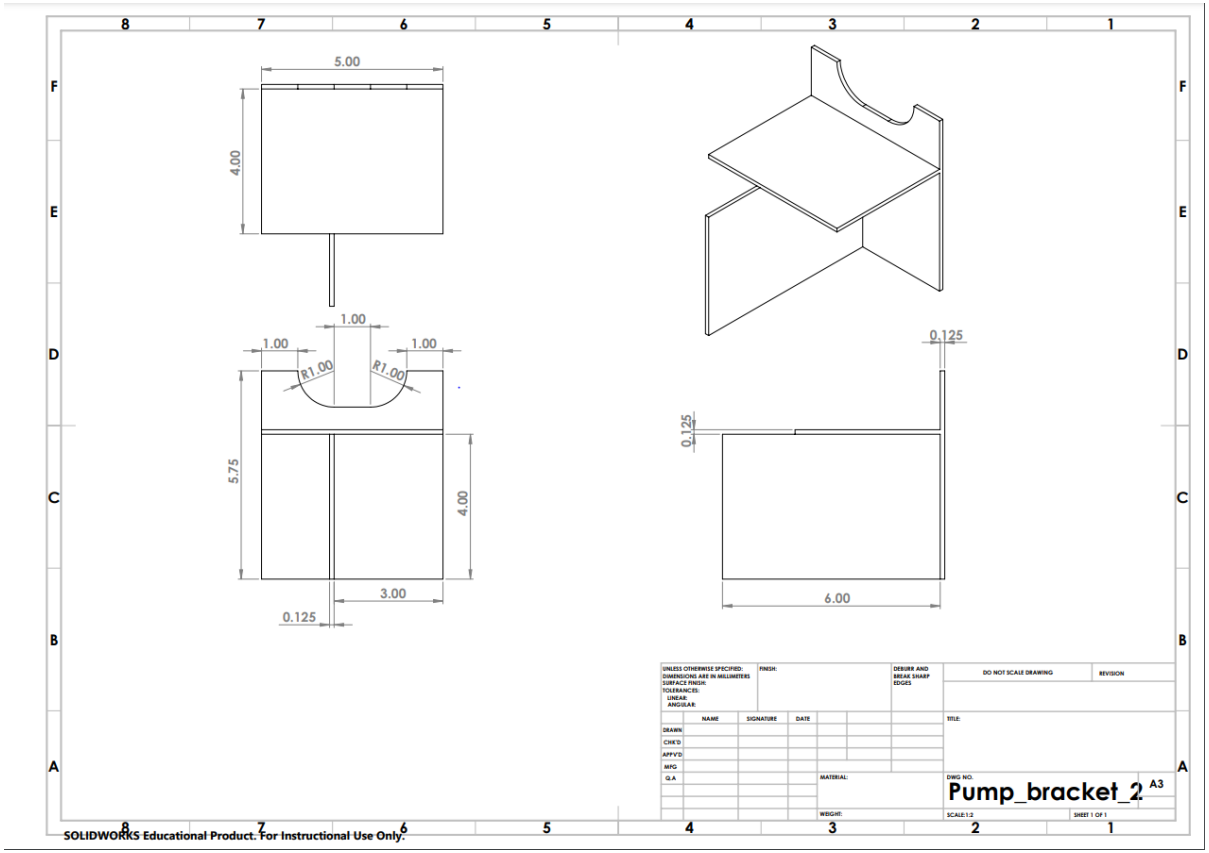
- 80/20 Component Framework
  - T-Slot mounting hardware
  - High Tensile Strength
  - Lightweight

Custom Made Parts

- Pump mounting bracket
- Mig welded 0.1625" steel by WMU machine shop
- Secured onto frame with 5/16" U-bolts

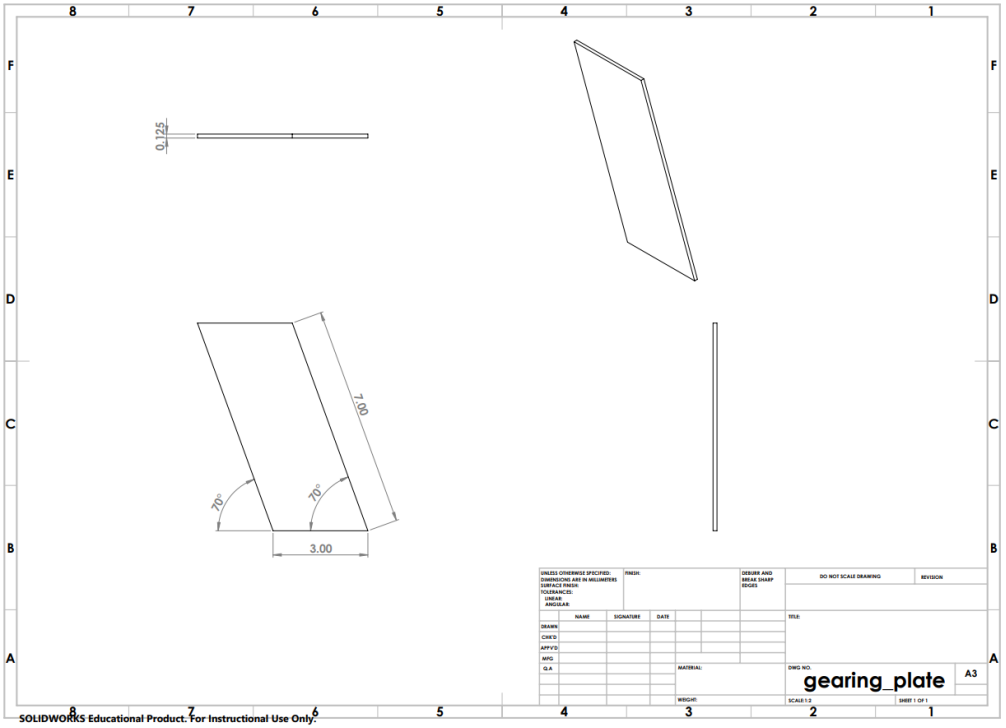






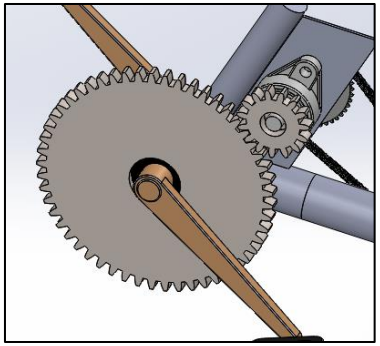
Custom Made Parts

- Gear mounting platform
- Welded onto frame while still adjustable
- 1st set gear ratio = 100:20
- 2nd set gear ratio = 48:9
- Pedal to pump = 1:26.67



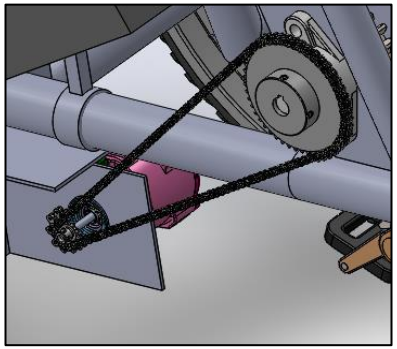
Gear Ratio

Pedal to Pump



100:20

+

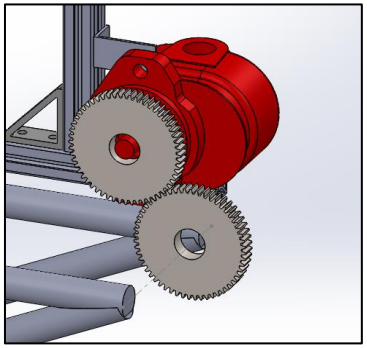


48:9

=

1:26.67

Motor to Driving Wheel (rear)



1:1

Gear Speed Hub

- Shimano SG-8R25 (8 Speed Internal Rear Hub)
- 302% Gear range
- Connected to driving wheel and motor

8	1.615:1
7	1.419:1
6	1.223:1
5	1:1
4	0.851:1
3	0.748:1
2	0.644:1
1	0.527:1

Electronics

- 5 Gang Switchtec Switchbox with Digital Voltmeter Display
- 12 VDC DIN Coil (J & H Series) 30W (2.5 Amp at 12V)

- Lithium-Ion Battery (1.87lbs)
- 70% lighter than lead acid battery
- Short-circuit and Output Overcurrent Protection

Specification:

Type of Battery: Li-ion(NCM)

Nominal Voltage:11.1V

Nominal Capacity: 9Ah (99.9WH)

Max Charge Current: 4 Amp

Max Continuous Discharge Current: 15 Amp

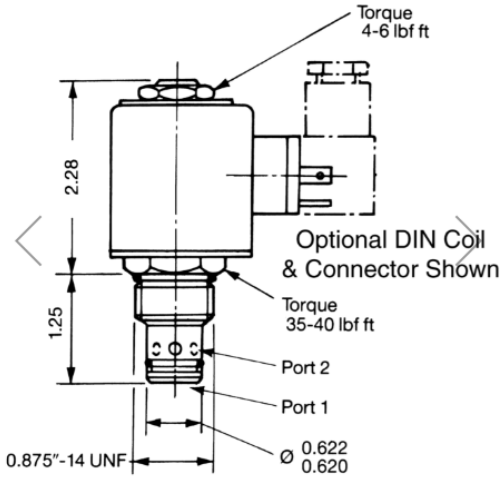
Max Pulse Discharge Current: 30A for 3S

Working Voltage range: 9V~12.6V

Charge Temperature: 0~45℃

Discharge Temperature: -10~+60℃

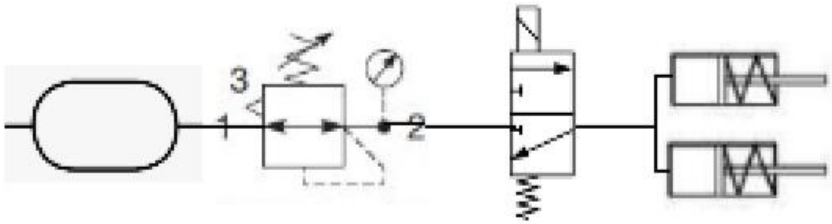
Storage Relative Humidity: 65±20%



Pneumatic Components

- Air Brakes (Parking Brake and Auxillary)
  - Bimba Air Reservoir (3"bore x10"length)
  - Bimba Mini Regulator
  - Pneumadyne high flow 3-Way 2-Position Valve
  - 2 Tolomatic Pneumatic P-10 Single Acting Caliper Brake
  - ¼" OD Polyurethane Tubing

Pneumatic Brakes System



From air reservoir

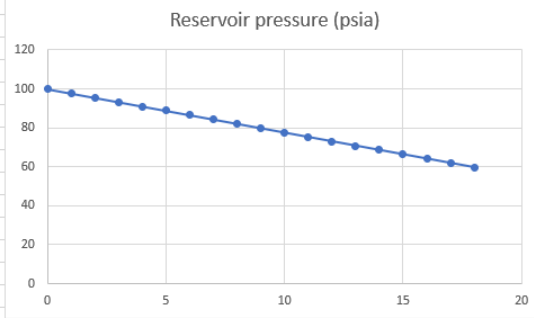
To tee then split to two caliper brakes

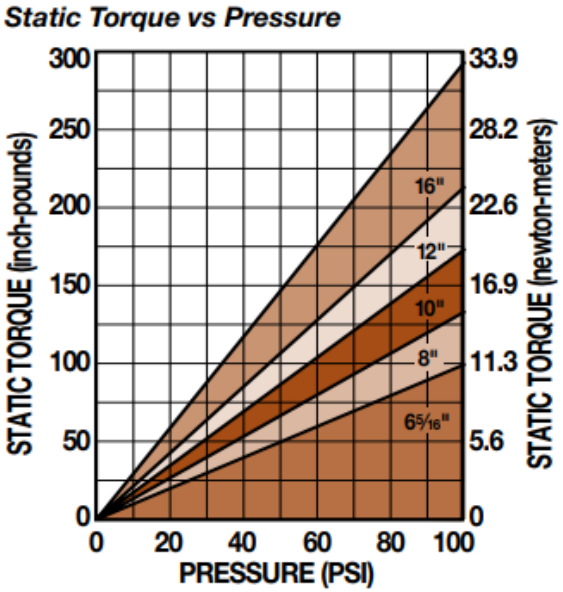
Pneumatic Calculations

- 60 PSI Lower Limit to develop 175-inch pounds of Static Torque
- (Calculated Torque for vehicle motion = 82-inch pounds)
- Brake Deployment of 18 brake cycles using 70 cubic inch reservoir

B9 =B8 - ($B$4-$B$3)*$B$1/$B$2

	A	B	C
1	Volume of brake system	3.5	in^3
2	Volume of reservoir	70.69	in^3
3	Atmospheric pressure	14.7	psia
4	Brake cylinder pressure	60	psia
5	Initial reservoir pressure	100	psia
6			
7	Braking cycle	Reservoir pressure (psia)	
8	0	100	
9	1	97.7571085	
10	2	95.514217	
11	3	93.27132551	
12	4	91.02843401	
13	5	88.78554251	
14	6	86.54265101	
15	7	84.29975951	
16	8	82.05686802	
17	9	79.81397652	
18	10	77.57108502	
19	11	75.32819352	
20	12	73.08530202	
21	13	70.84241052	
22	14	68.59951903	
23	15	66.35662753	
24	16	64.11373603	
25	17	61.87084453	
26	18	59.62795303	

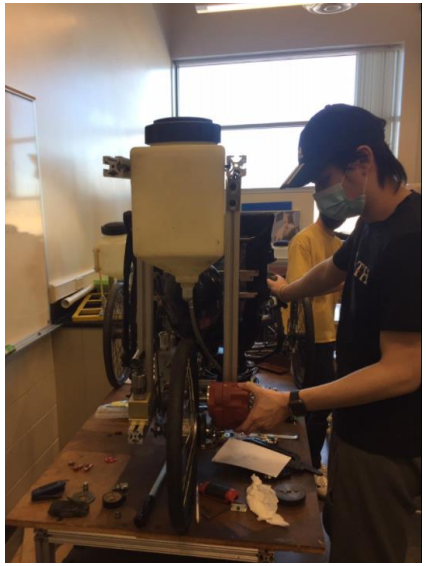




Pneumatic Brakes

Vehicle Construction

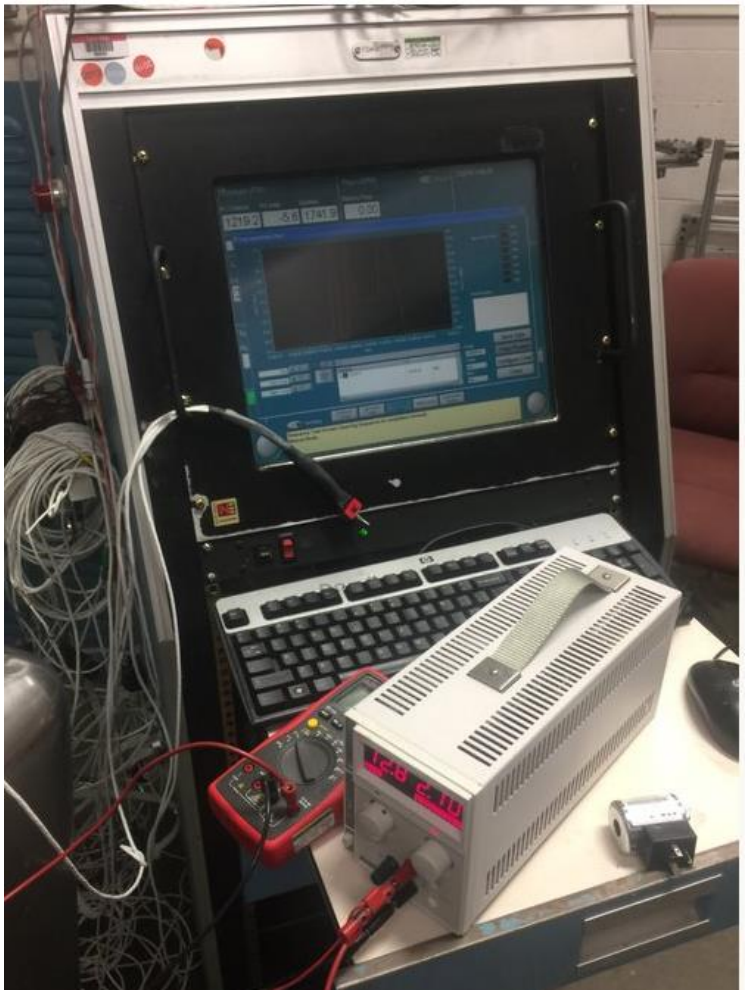
- Disassembly and component mock-up done on apartment floor.
- Further assembly of components done in WMU Fluid Motion Lab.
- Cutting of 80/20 framework and fabrication/installation of stainless-steel hydraulic lines done at Parker Hannifin Maintenance Dept.



Testing and Analysis

- Pressure testing accumulator and motor circuit

Testing and Analysis



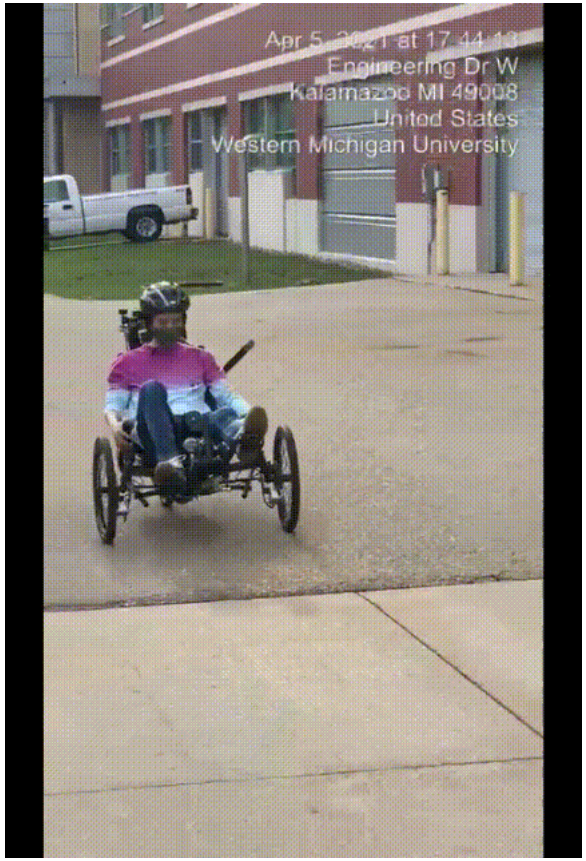
Final Design

Race Results

Efficiency Race	
1st attempt	14%
2nd attempt	12%
Average	13%

Sprint Race	
1st attempt	32.41 sec
2nd attempt	36.22 sec
Average	34.21 sec

<u>Endurance Race:</u> Not performed

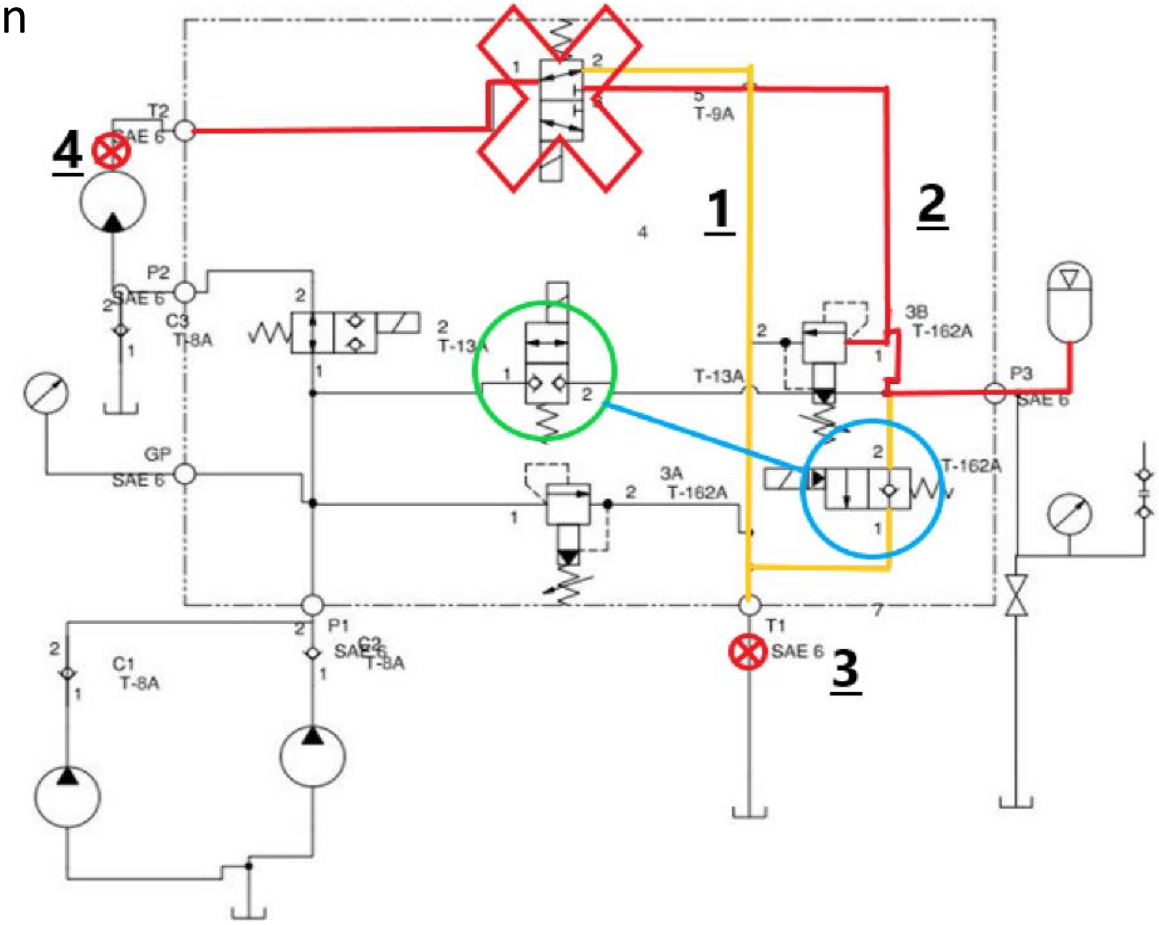


FARs (failure analysis report)

- Lithium battery failure
- Gear ratio too high to pedal from stand still

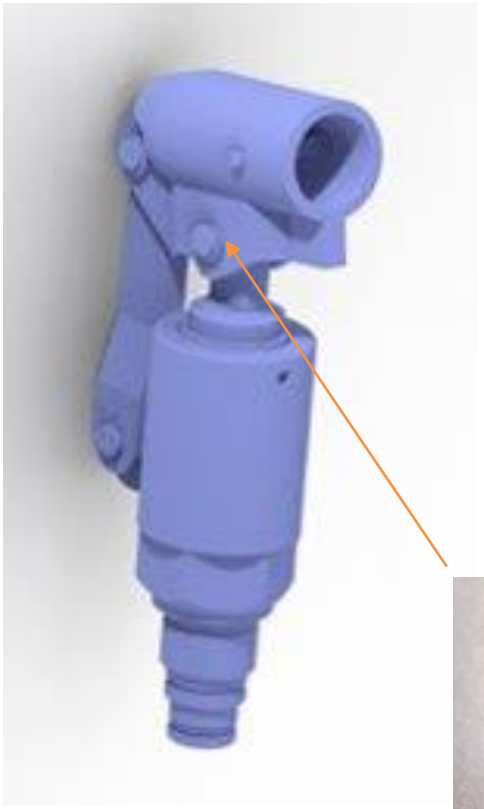
FARs (failure analysis report)

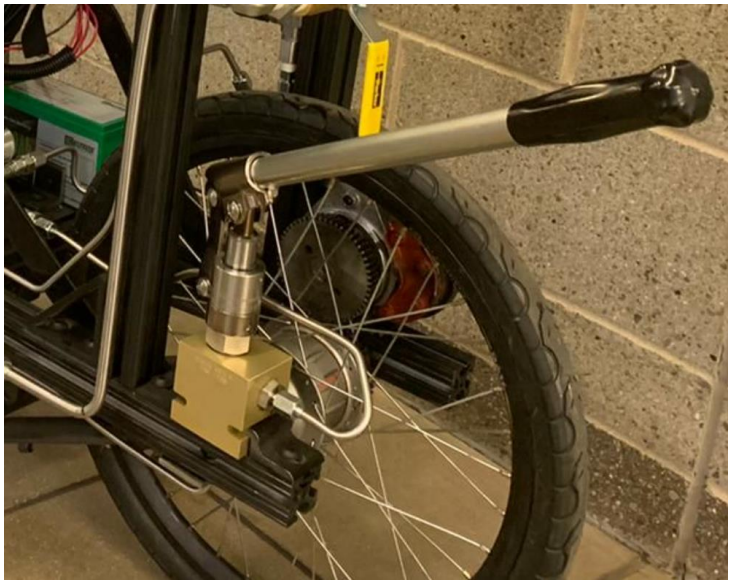
- Manifold leak to return lines
- Motor shaft seal extrusion



FARs (failure analysis report)

- Hand pump failure





Lessons Learned

- Accurate 3D modeling reduces build time
- Order back-ups for troubleshooting
- Order more variety for experimentation
- Stay on top of orders verifying placement
- Extensively test parts individually on arrival
- Time management with action items and procedures
- How to get parts fabricated

Thank you

- NFPA for the experience
- Stephanie Scaccianoce, Jeff McCarthy, and Kent Sowatzke
- Mentors: Patrick Petroff and Dean Pollee
- Advisors: Dr. Jorge Rodriguez, Dr. Alamgir Choudhury, Dr. Javier Montefort
- WMU machine shop specialist: Mike Konkel

Questions and inquiries?