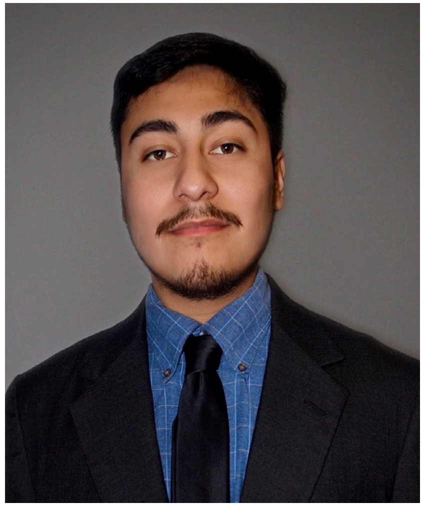
10 YEARS NFPA Fluid Power Vehicle Challenge

NFPA
Education and
Technology
Foundation

FINAL PRESENTATION & DESIGN REVIEW
North Carolina Agricultural and Technical State University
Dr. Paul M. Akangah
4/6/2026

Team Introduction

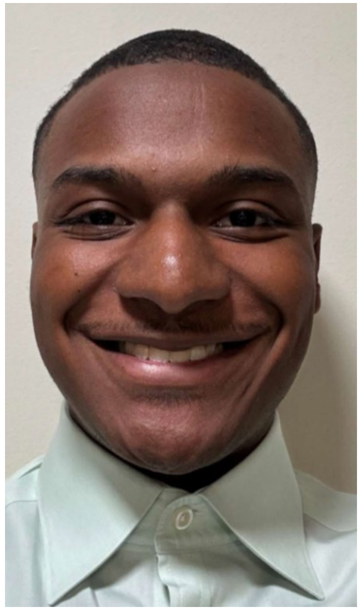


David Castro
Team Lead &
Hydraulics Lead

Jose Villa
Controls Lead & Pneumatic Leads

Joshua Williams
Drive Train Lead

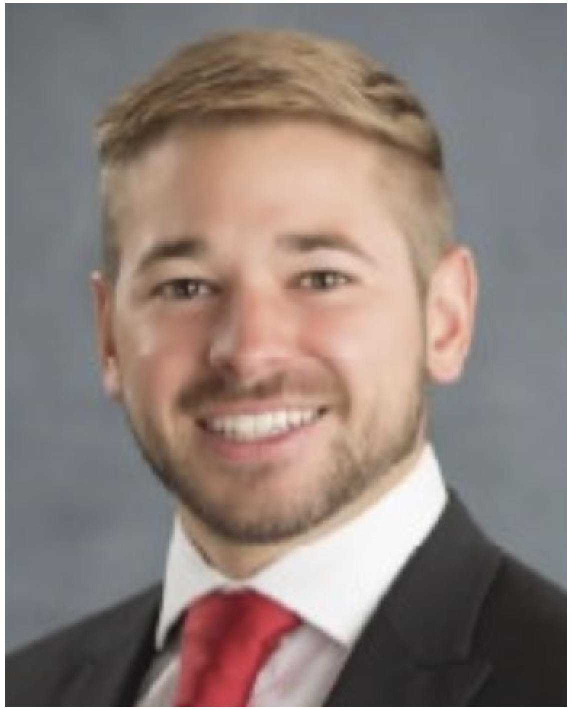
Jabari Wilson
Integration Lead



Isaiah Washington
Manufacturing
Lead

Advisor, Mentor, and Technical Liaison

Advisor
Dr. Paul M. Akangah



Mentor
Mr. Garrett D. Bialosky
Parker-Hannifin

Technical Liaison
Mr. Steve Gluck

Acknowledgement

- We want to thank the National Fluid Power Association (NFPA) for financing and providing the resources to enable a successful attempt at the Fluid Power Vehicle Challenge (FPVC). We also want to thank our mentor, Mr. Bialosky, from Parker-Hannifin Corporation, as well as our Technical Liaison, Mr. Gluck, for their contribution and support. Lastly, we are also thankful to Dr. Akangah for his guidance throughout the development of the project.

Rear Frame

Disadvantages:
- Poor maintenance access
- Clustered component layout
- Poor material selection
- Poor fasten methods of components

Improvements:
- Aluminum t-slotted rails and tray
  - Reduce weight and material oxidization
- Aluminum brackets
  - Secure components properly to vehicle

Reusing:
- Aluminum bike frame

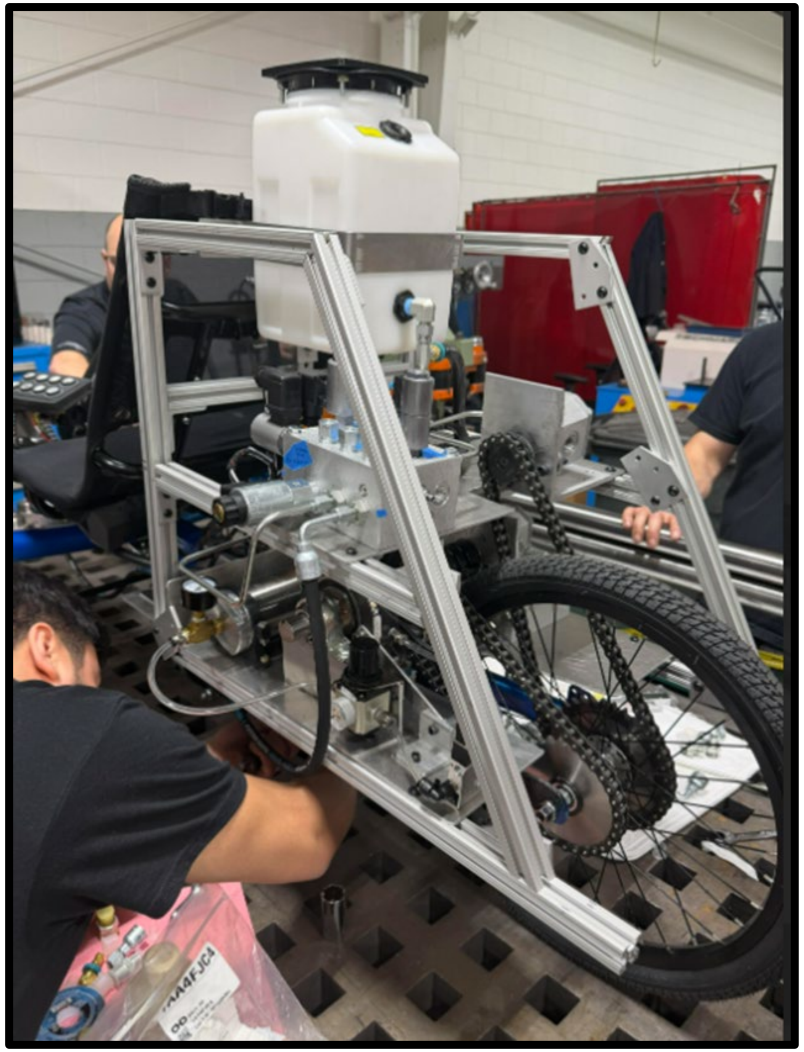


Fig. Rear Frame

2025-2026 Vehicle

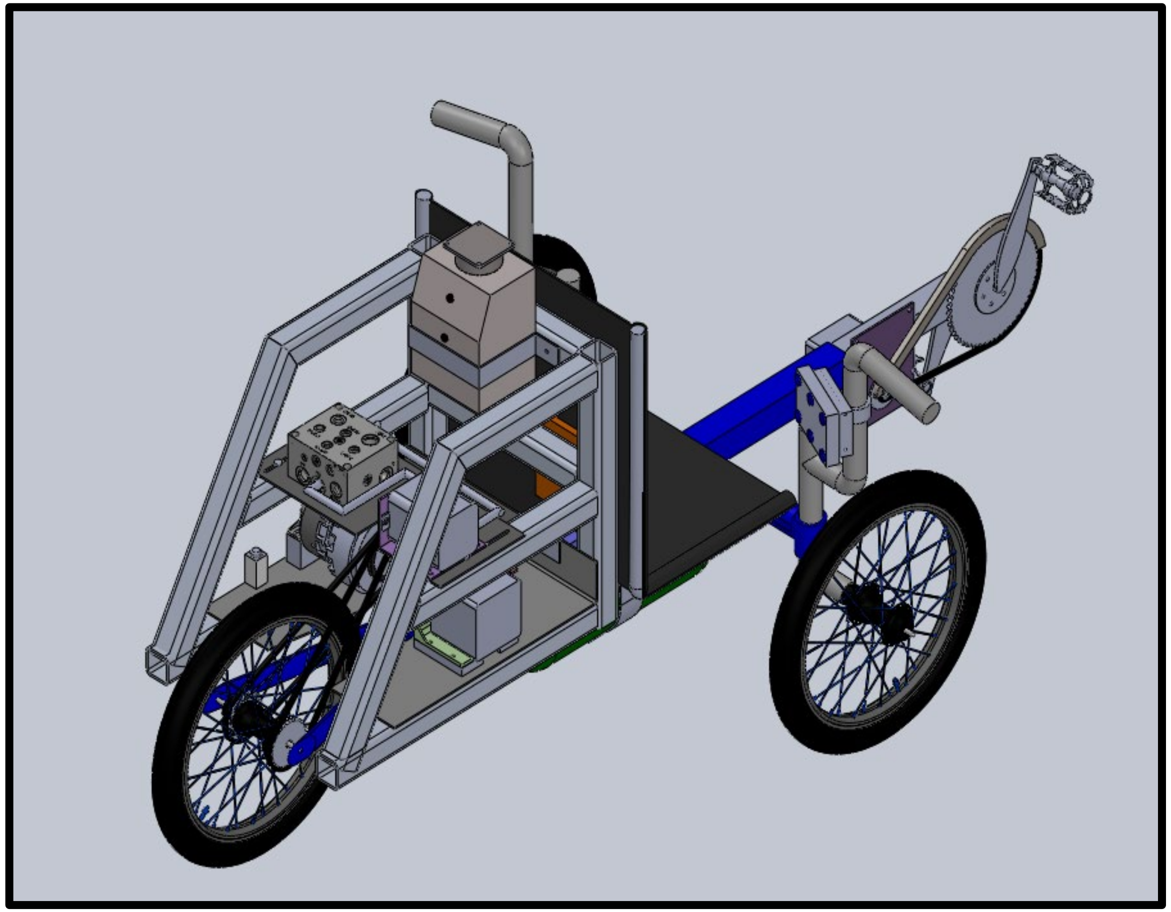


Fig. CAD Model

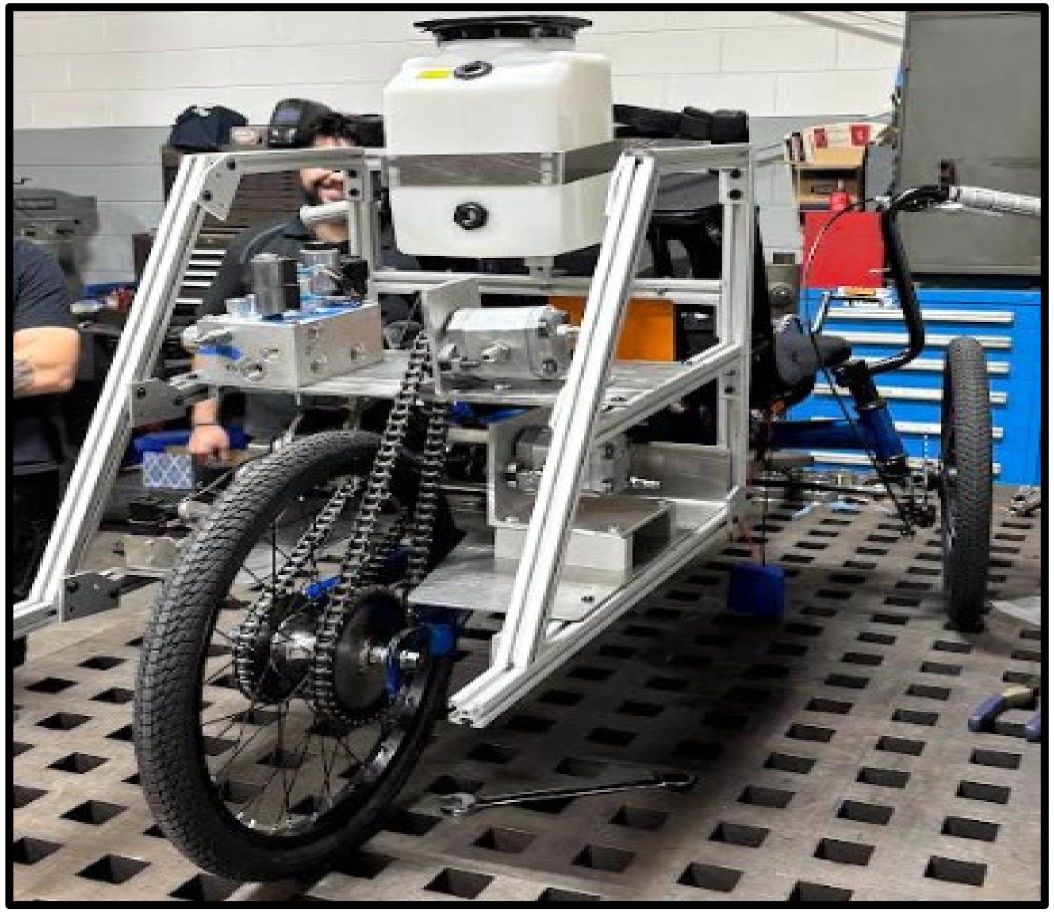


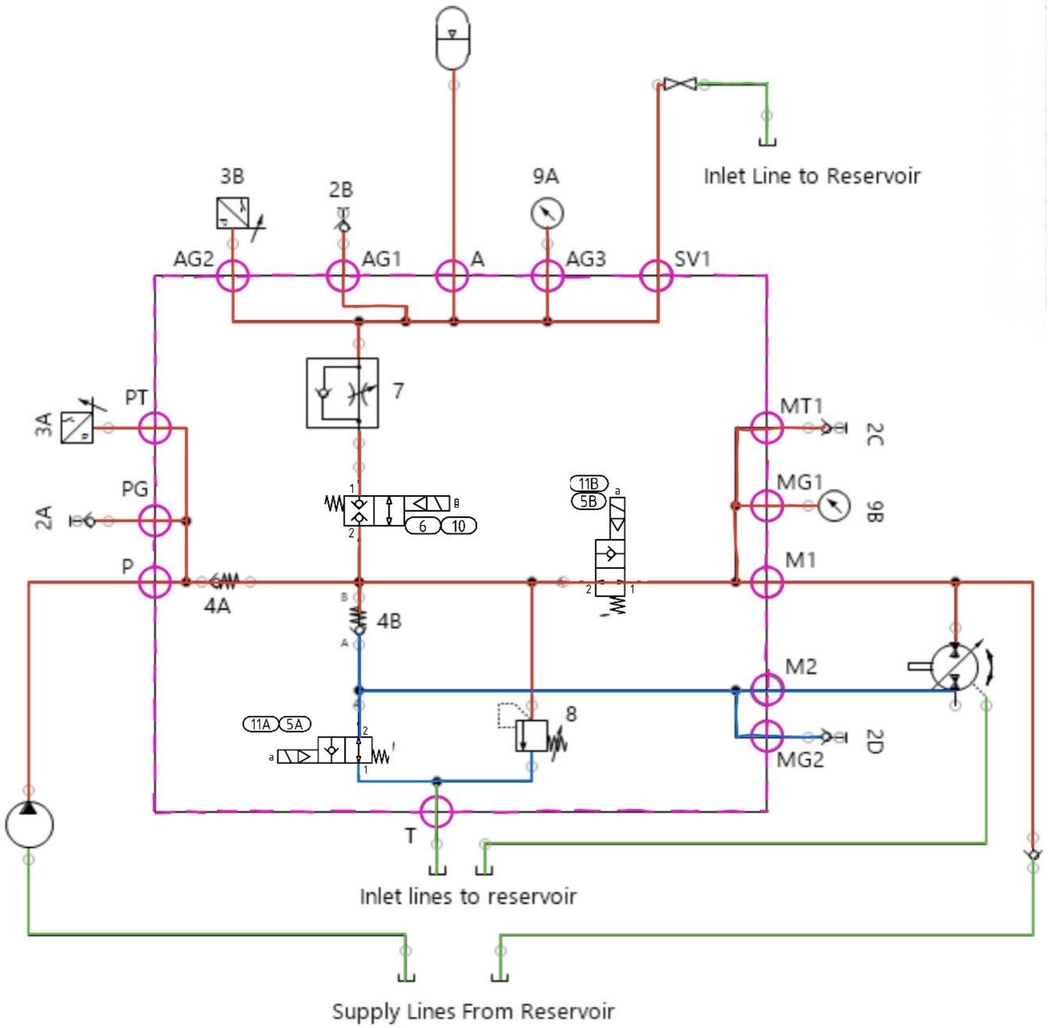
Fig. Bike

Vehicle Testing

- Top Speed
  - 17 mph
  - 250 ft in 25 sec.
    - Direct drive only
- Accumulator Charging
  - 1200 psi
  - 1 min 44 sec.
  - Pre-charge: 50 psi
- Regen Braking
  - Difficult to build charge from standing start

2024-2025 Hydraulic Circuit (old)

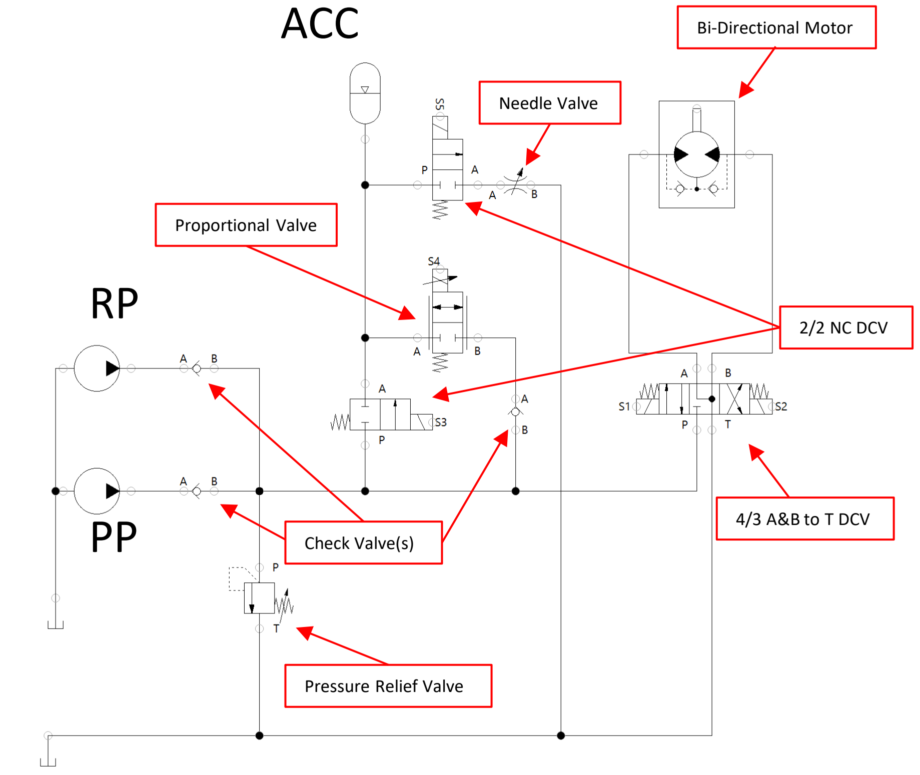
- **Bi-directional motor**
  - Used for regen braking
  - Hydraulically Locked when moving in reverse
- **Flow control valve**
  - Meter-out accumulator discharge
- **Shut-off valve**
  - System dump
- **2/2 NO DCV**
  - Direct Drive
  - No Float Position



Hydraulic Drive Modes				
Mode	Valves			
	H1	H2	H3	M1
Direct Drive	0	0	0	0
Accumulator Charge	1	1	0	1
Regenerative Braking	1	1	1	1
Accumulator Discharge	1	0	0	1
System Dump	0	0	0	0
Coast	0	1	0	0

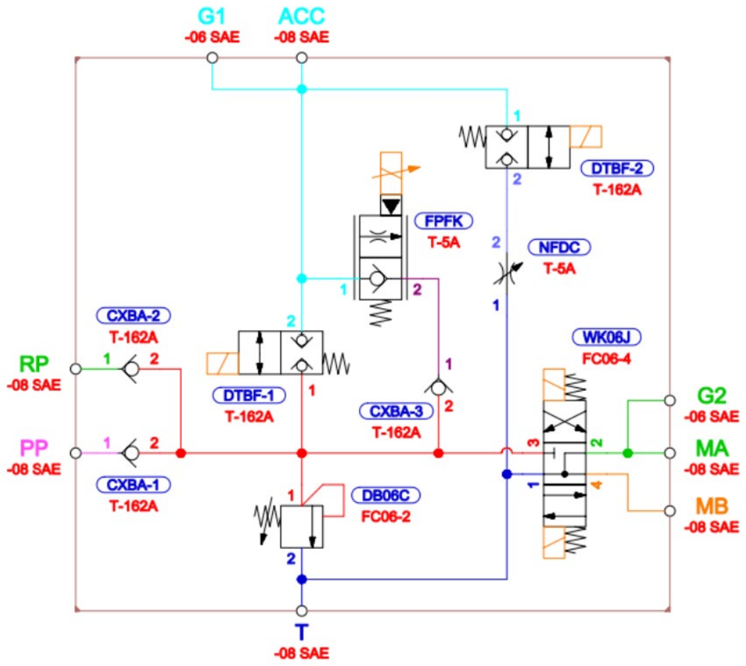
2025-2026 Hydraulic Circuit (new)

- **Dedicated Regen Pump (RP)**
  - More efficient than bi-directional motor
- **Proportional Control Valve**
  - Meter-out accumulator (ACC) discharge
- **2/2 NC DCV**
  - System Dump
  - preset Needle Valve opening level
- **4/3 A&B to T DCV**
  - Added reverse drive
  - Center float position (Neutral Drive)



Solenoid	S1	S2	S3	S4	S5	CLUTCH
DD	1	0	0	0	0	0
AC-pedal	0	0	1	0	0	0
AC-regen	0	0	1	0	0	1
AD	1	0	0	1	0	0
DUMP	0	0	0	0	1	0

Fig. Hydraulic Circuit

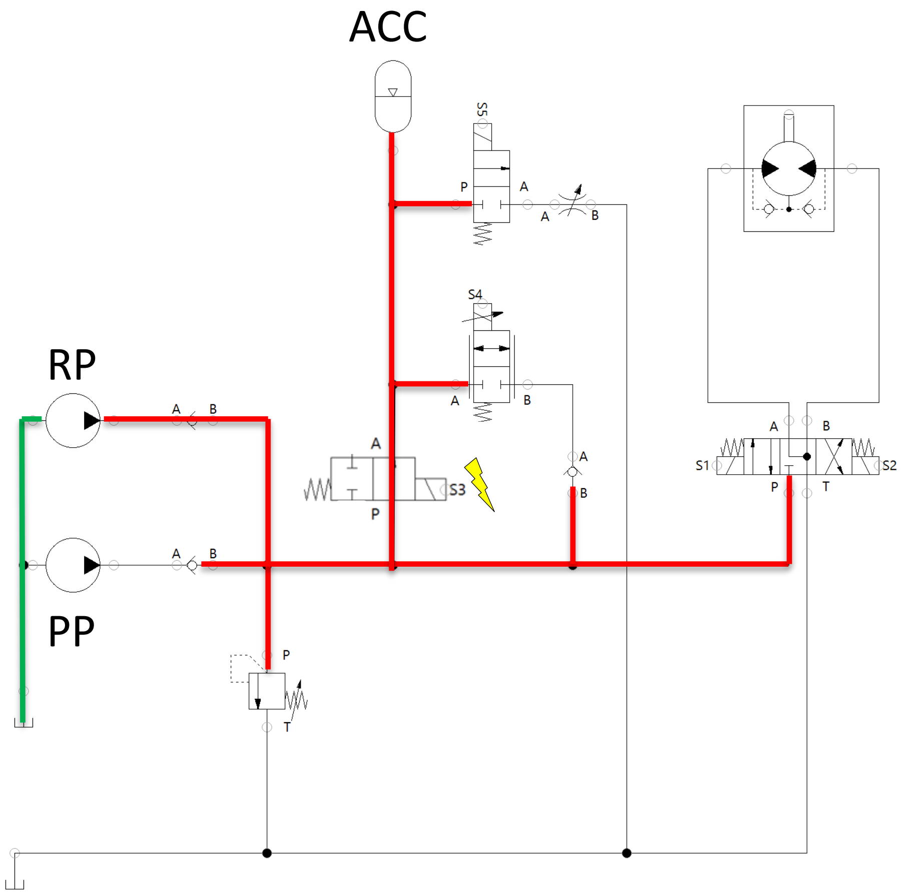


Ports		
G1, G2	0.562-18 SAE Port	
ACC, MA, MB, PP, RP, T	0.750-16 SAE Port	
Valves		
DB06C	Hydac FC06-2	0.562-18UNF
WK06J	Hydac FC06-4	0.562-18UNF
FPFK, NFDC	T-5A Sun	1.000-14 UNS
CXBA-1, CXBA-2, CXBA-3, DTBF-1, DTBF-2	T-162A Sun	M16 x 1.5mm
Mounting holes		
4x	Diam 0.344 Thru	

Fig. Manifold Schematic

2025-2026 Hydraulic Circuit

- <u>Regenerative Circuit</u>
  - Pneumatic clutch & solenoid S3
    - electronically engaged
  - Power transmitted
    - from rear wheel to clutch
    - from clutch to regen pump (RP)
  - Regen Pump (RP)
    - pushes hydraulic fluid through the 2/2 NC DCV into the accumulator
  - Accumulator
    - stores energy, slowing the vehicle (braking)



Solenoid	S1	S2	S3	S4	S5	CLUTCH
DD	1	0	0	0	0	0
AC-pedal	0	0	1	0	0	0
AC-regen	0	0	1	0	0	1
AD	1	0	0	1	0	0
DUMP	0	0	0	0	1	0

Hydraulic Calculations

Key Calculations
- Power required at wheel = 221.19 W
- **Torque at wheel = 22.62 Nm**
- Wheel speed = 93.37 rpm

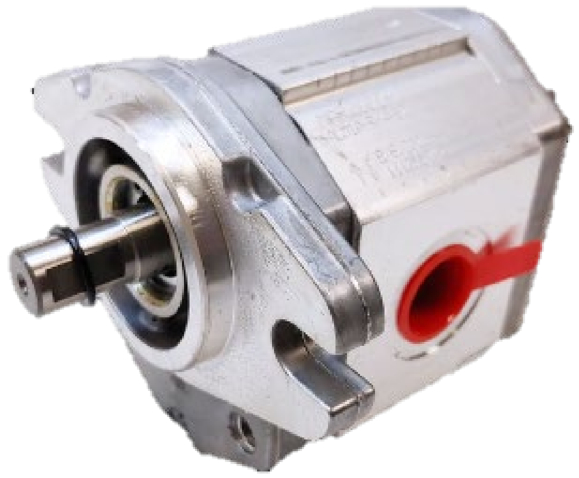
- Motor Torque = 5.66 Nm
- **Flow-rate = 1.39 L/min**
- **Motor size = 3.35 cm^3/rev**
- GR = 4:1 (theoretical)

Assuming no losses
- Pump Torque = 11.954 Nm
- **Flow-rate = 1.39 L/min**
- **Pump size = 4.41 cm^3/rev**

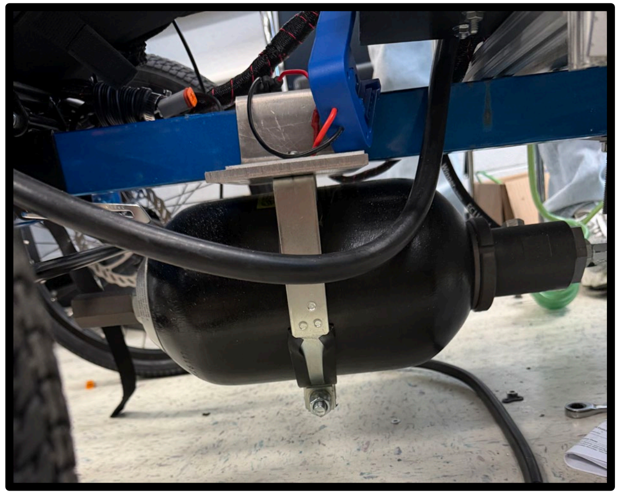
Human Input
- Power required = 438.12 W
- **Human torque = 61 Nm**
- **Pedal speed = 68.58 rpm**
- GR = 5:1 (theoretical)

Hydraulic Components

Marzocchi ALP1A-D-7
5.2cc



Marzocchi ALM1A-R-5-E2
3.5cc



Bladder Accumulator

Hydraulic Assembly

10 YEARS
NFPA
Fluid Power
VEHICLE
Challenge

- Optimized hydraulic assembly integrates the pump, motor, and drivetrain for efficient power transfer in both drive and discharge modes.

- **Vehicle Plumbing**
  - Thermoplastic hoses
  - Rigid tubing
- **Pressure lines**
  - downsized to SAE -04
- **Suction lines**
  - downsized to SAE -06
- **Reservoir**
  - Mounted above hydraulic components for increased efficiency
- **Motor**
  - Inline with manifold to reduce pressure losses

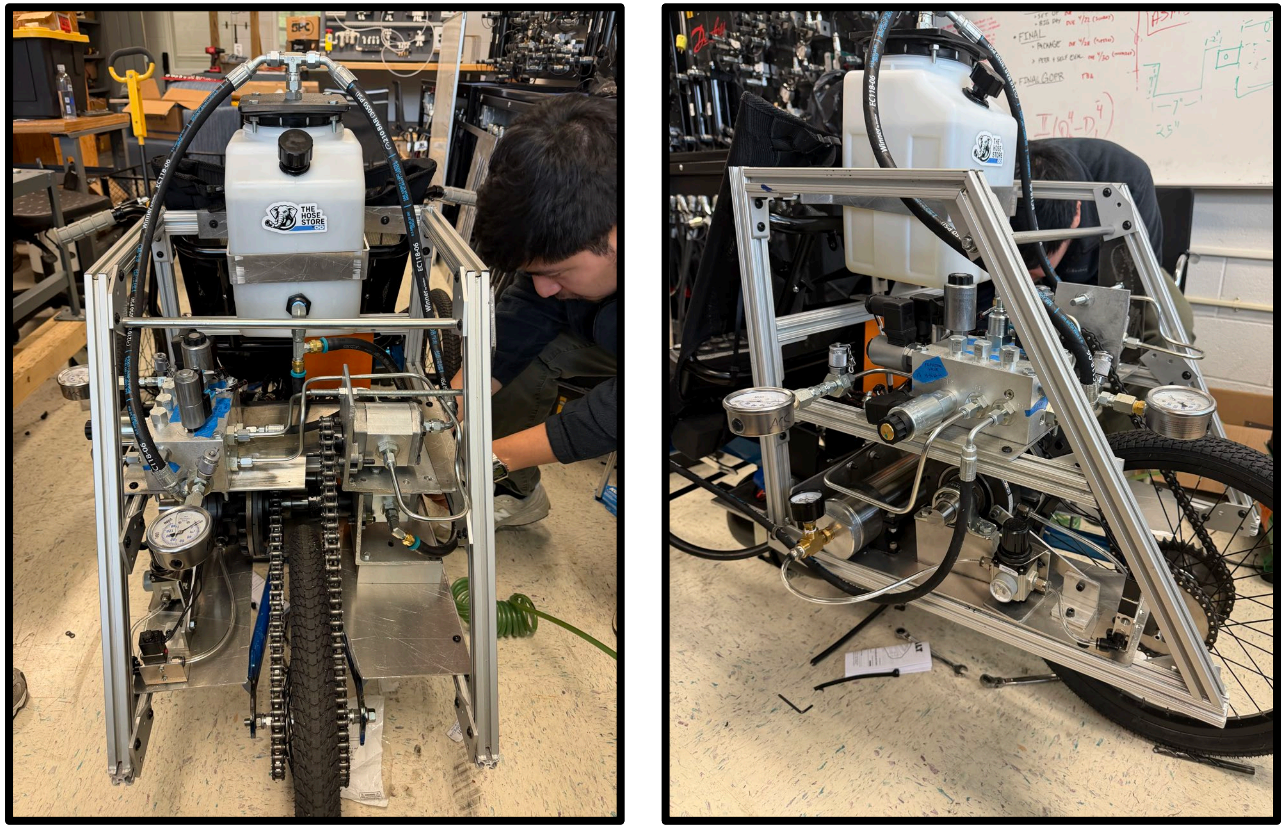


Fig. Completed Bike Assembly

Pneumatic Circuit

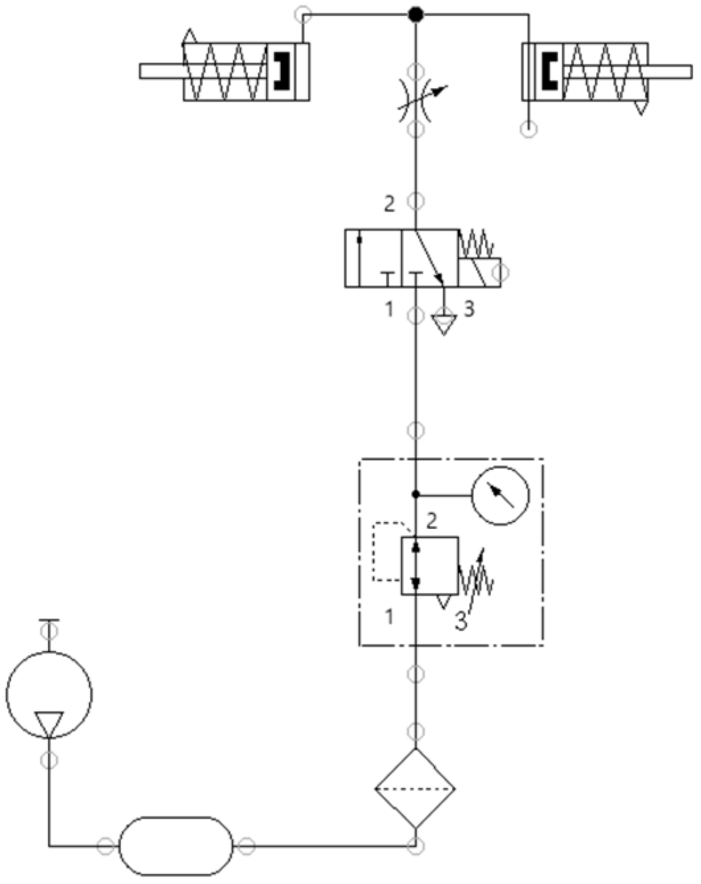


Fig. 2025 Circuit
(old)

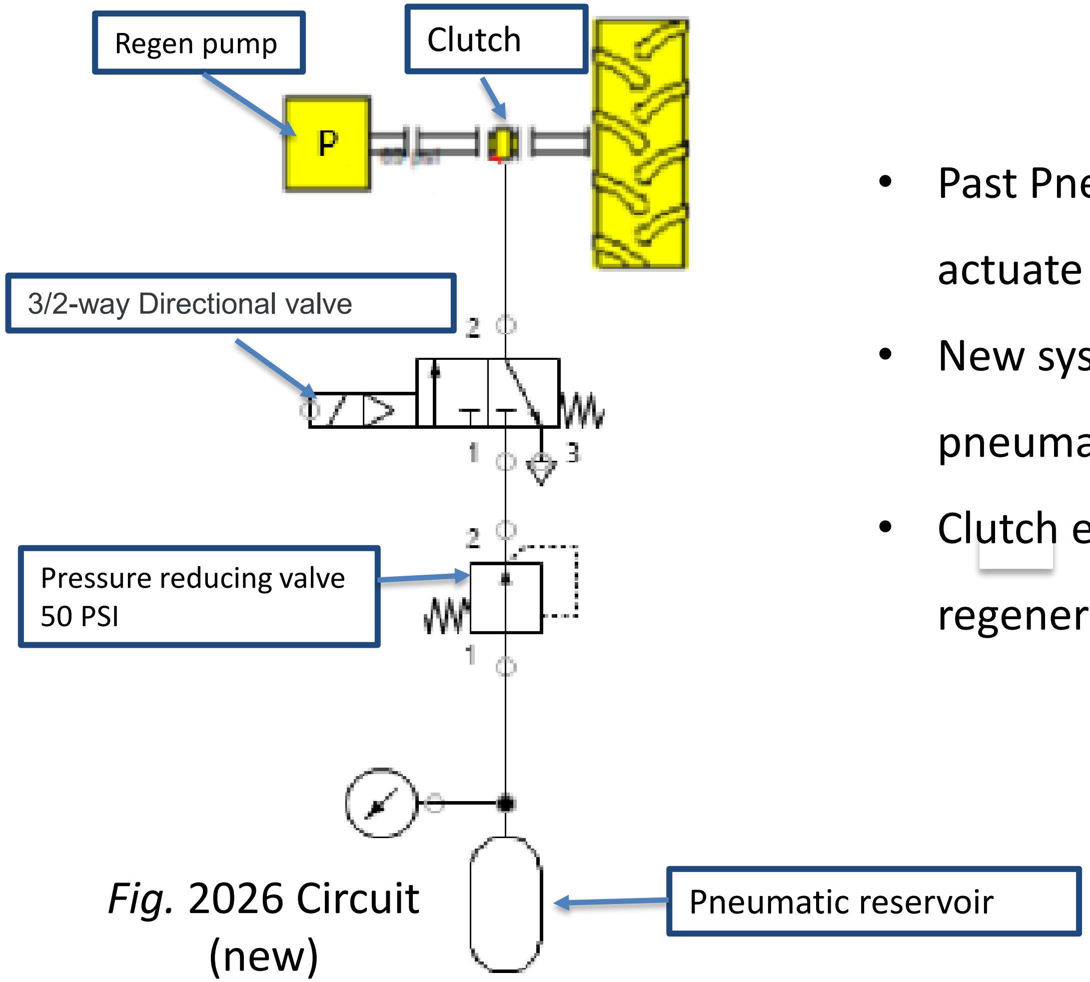


Fig. 2026 Circuit
(new)

- Past Pneumatic circuit was used to actuate a kick-stand
- New system is used to actuate a pneumatic clutch
- Clutch engages regen pump for regenerative braking

Pneumatic Components

Pneumatic Reservoir

3/2 Directional control Valve

Pressure relieve Valve

Nexen L600 clutch

Pneumatic Clutch & Mounts

- Pneumatic clutch mount
  - 3D printed mounts failed test
  - Redesign mount using misaligning bearings and aluminum block
  - Installed misaligning shaft sleeve to integrate the regenerative pump

- Pumps and Motor
  - 3D printed mounts failed test
  - Designed and manufactured aluminum mounts

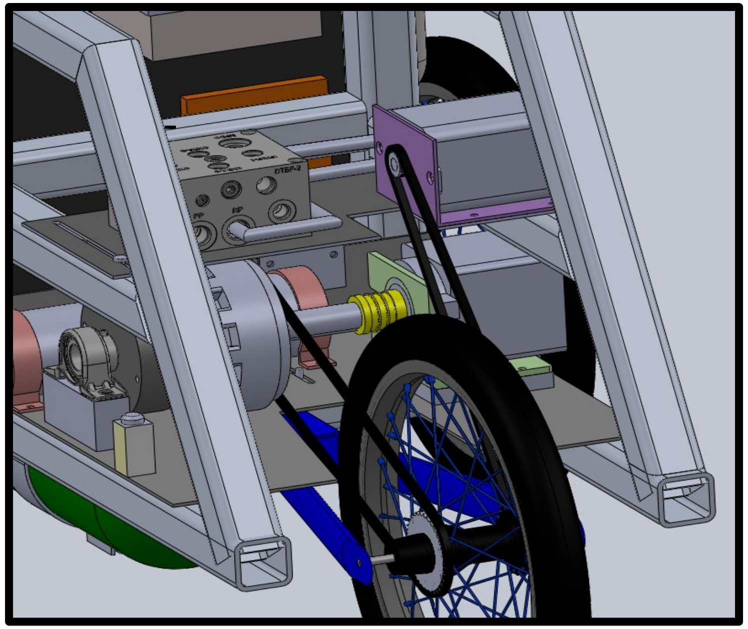


Fig. Pneumatic clutch setup

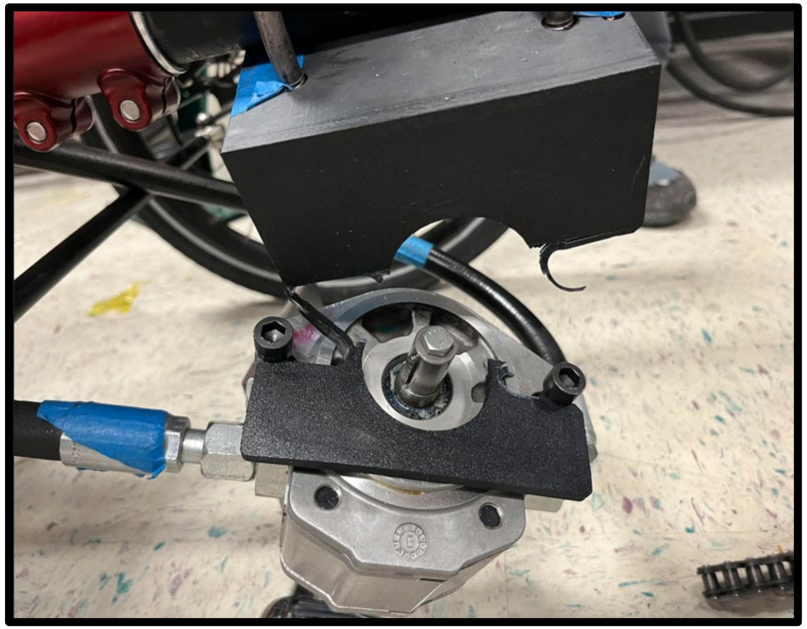


Fig. 3D printed pump mount

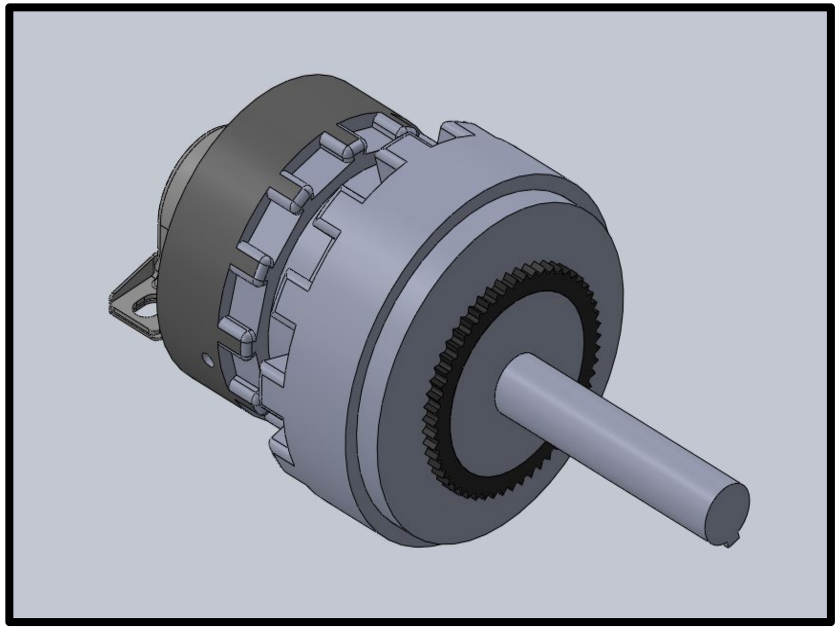
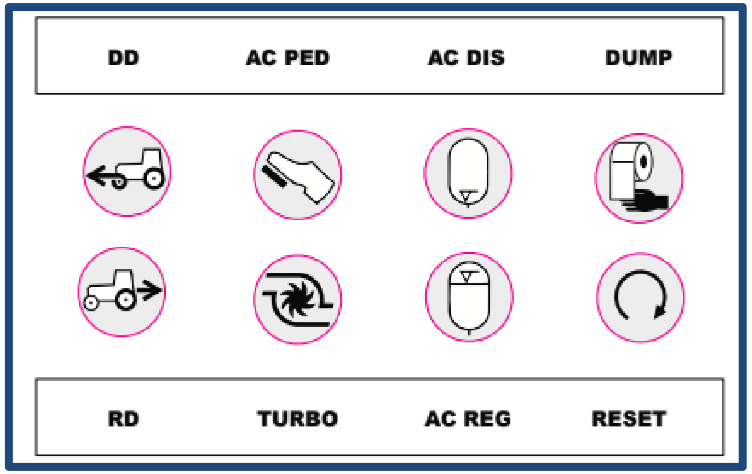


Fig. Pneumatic clutch

Controls

IFM CR413S



OPS Control Keypad Layout

Kobalt 24v Battery

2610161 Solenoid

770224 Solenoid

740224D solenoid

Drivetrain

- Dual sprocket system
  - – Wheel/Clutch ratio: 1:1
  - – Wheel/Motor 2:1
- Setup allows for simultaneous use of motor and charging for the clutch

Fig. Dual Sprocket System

10 YEARS NFPA Fluid Power Vehicle Challenge

Lessons Learned

- Ask for accumulator specs before ordering
- Test previous bike before disassembly
- Manufactures won’t help you if you use someone else's equipment
- Complete vehicle assembly earlier for more testing and optimization
- Ensure hydraulics is present during control development to confirm correct solenoid logic