



N F P A

Fluid Power

=VEHICLE

Challenge



NFPA
Education and
Technology
Foundation

**FINAL PRESENTATION &
DESIGN REVIEW
Pump Fiction
Kristin Smith
04/15/2026**



Introductions

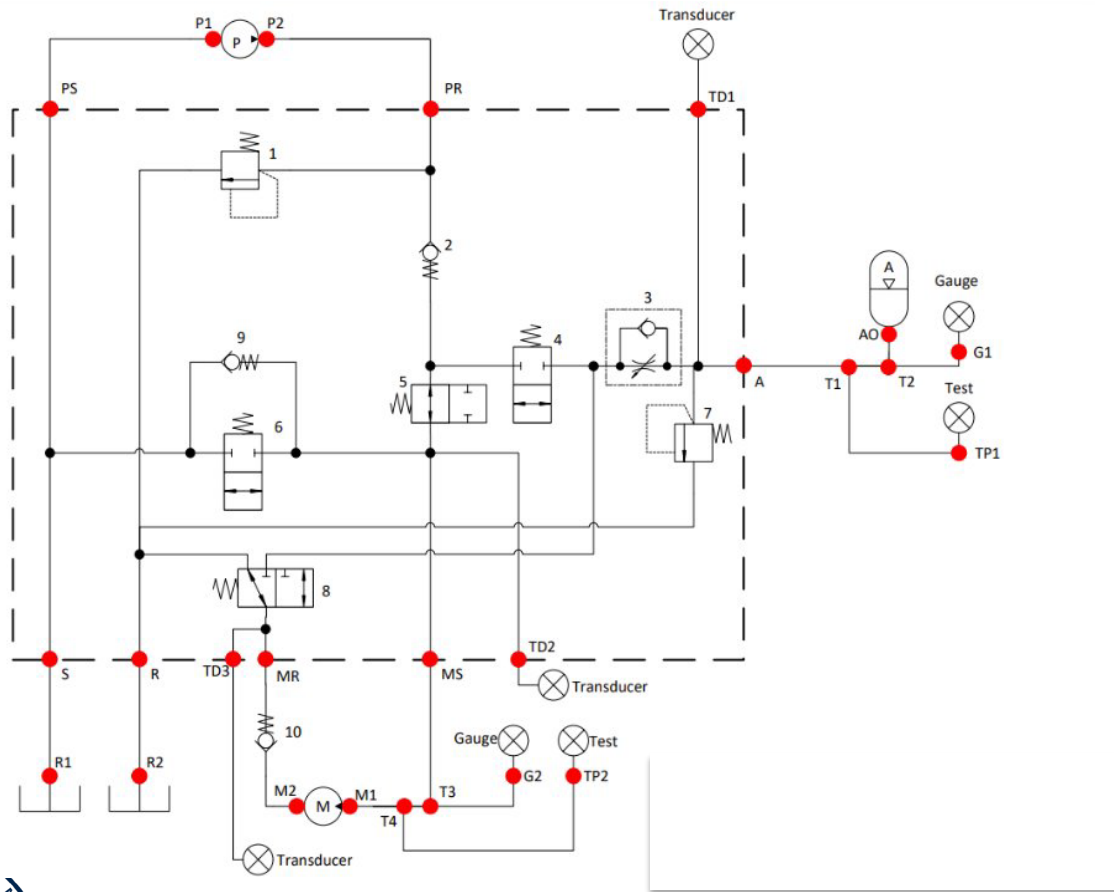


- Emmalea Yunk (Emma)
 - Project Lead/ Scrum Master
- Aiden Smith
 - EHS/ Safety Lead
- Bridget Paul
 - Social/Fundraising Lead
- Ryan Cassidy
 - Communications Lead
- Braden Fitzpatrick (Fitz)
 - Electrical Systems Lead
- Alex Ledajaks
 - Travel Lead
- Ben Roan
 - Chief Financial Officer

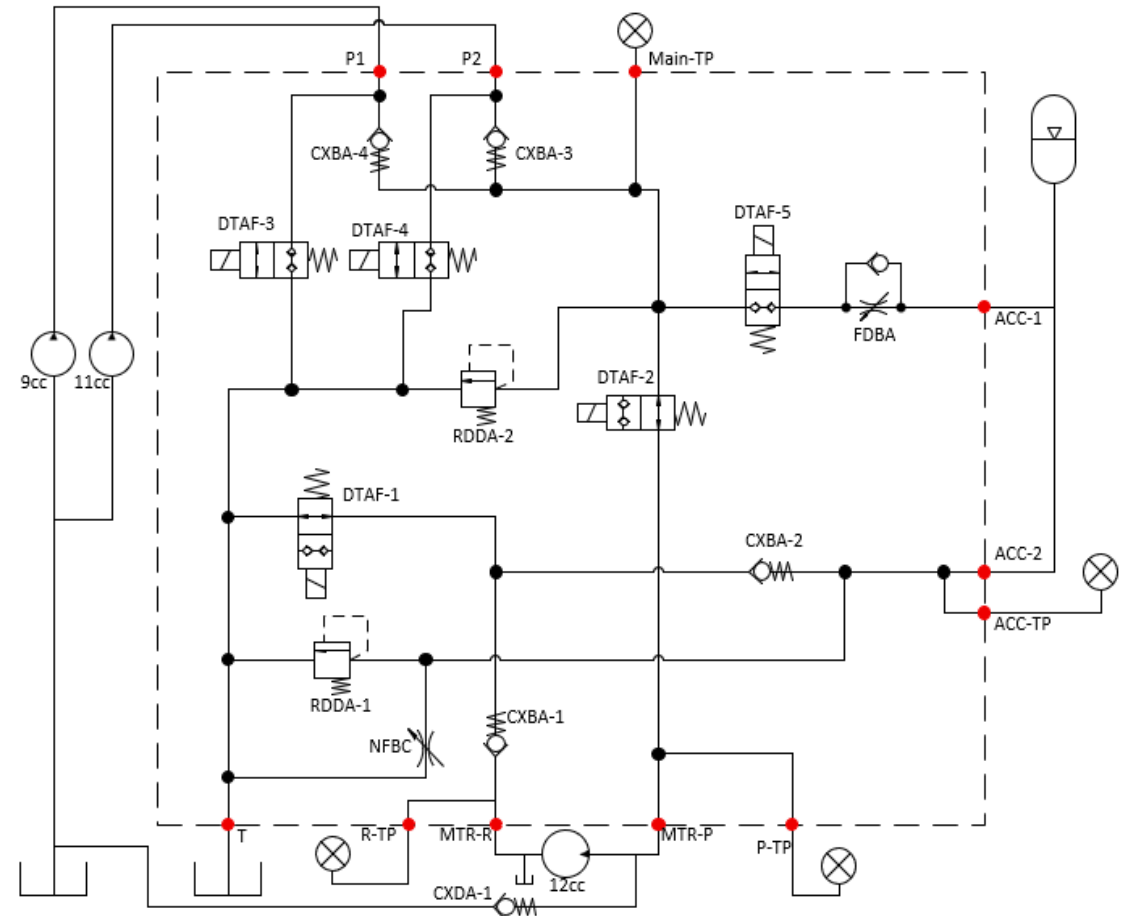
Hydraulic Circuit



2024-2025



2025-2026



Construction



(Pictured Above) Taken:
November 8th, 2025

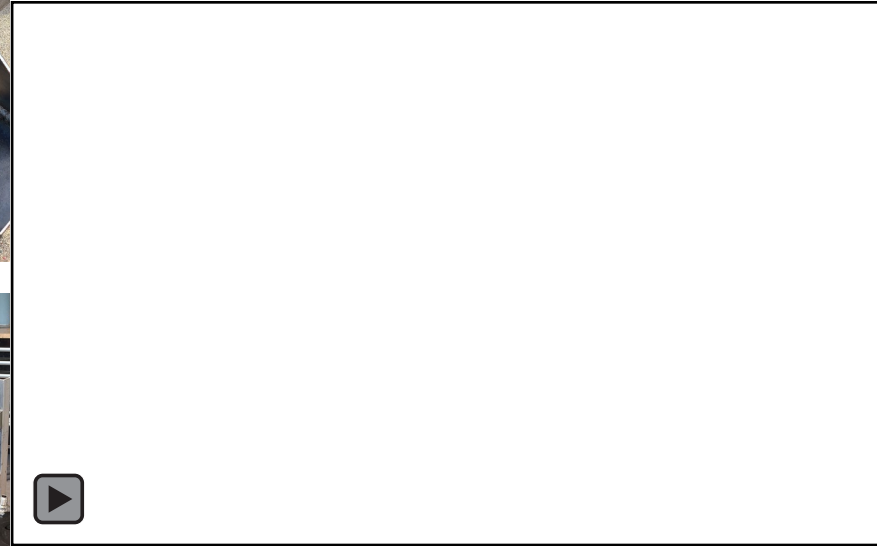
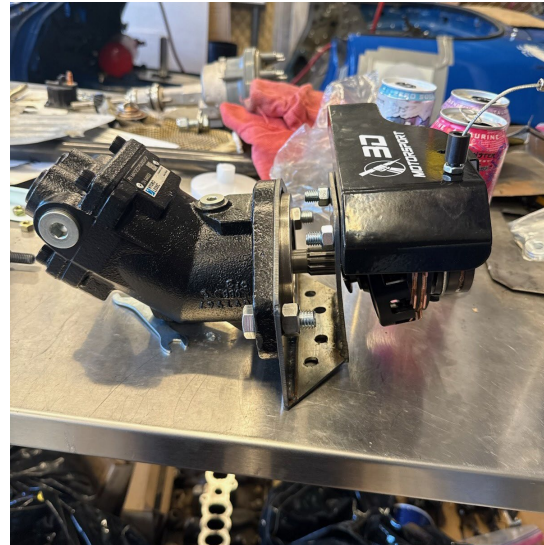
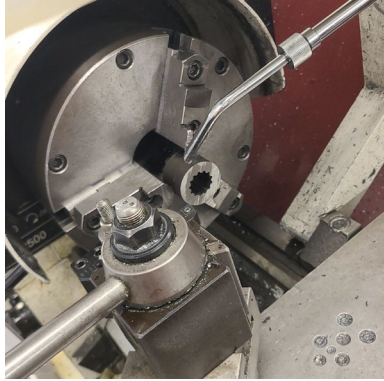


(Pictured Left & Above) Taken:
April 11th, 2026



Construction

After many design reviews and virtual work, the build began on February 10th and concluded on April 11th (60 days).





Controls Improvements

- Reduced complexity of the physical controls layout
- Created redundant physical and digital controls for critical functions.
- Used connectors at multiple points of wire runs to ease repair and disassembly.

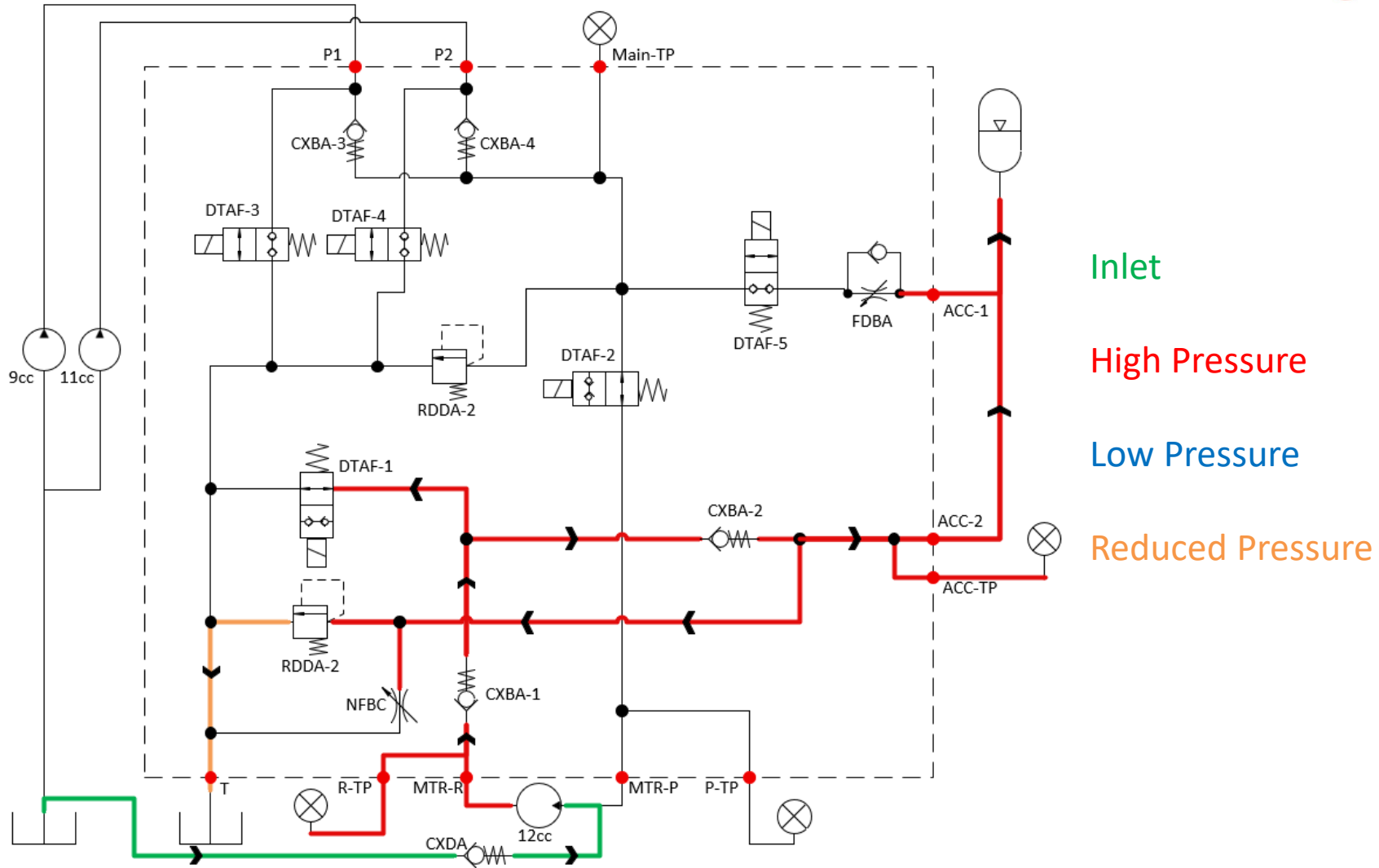


Improvements During Testing



Issue	Improvement Developed
Rear chain experienced jumping	Motor-driving gear swapped out for 50-tooth, also decreased force to pedal
Chain Guard would fold in on itself	Chain Guard was reinforced with aluminum plates
Bike experienced flexing at high pressure applications	Extra support was added to steel mounting base where pump caused deformation

Regenerative Braking Circuit



Inlet

High Pressure

Low Pressure

Reduced Pressure



Critical Design Choices

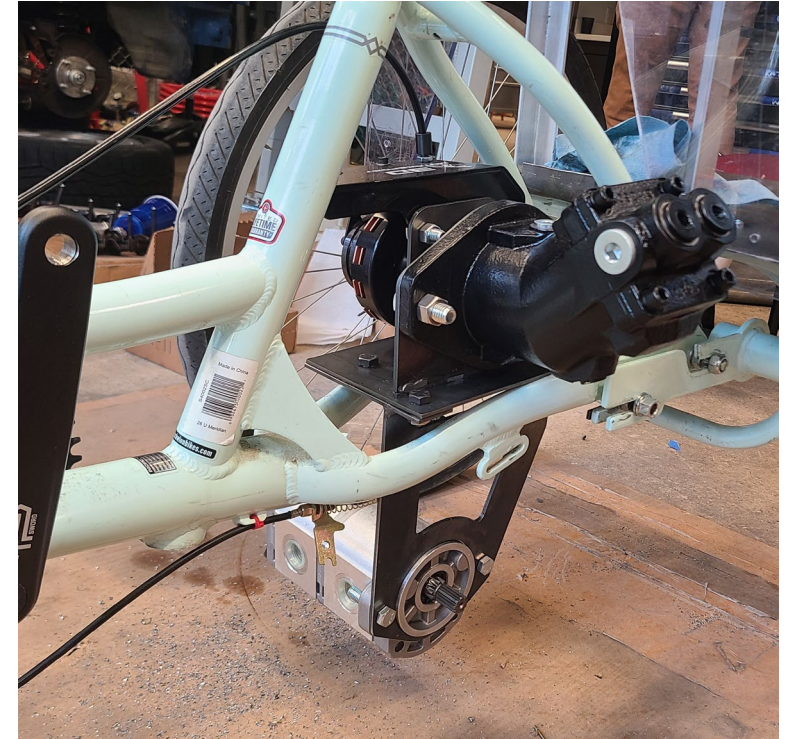


Pump – Dual-Outlet (9cc/11cc)

- Low displacement allows for better start-up torque
- Higher displacement allows for higher cruising speeds
- Different drive modes allow switching from acceleration to efficiency

Motor – 12cc Bent Axis Piston

- High efficiency – balanced torque and speed output
- Handles high pressure – reliable under loads



Motor, Clutch, and Pump placement allowed for alignment with pedals and rear axle gears



Critical Design Choices - Gearing

Pedal → Pump (44T → 14T, 3.14:1)

- Balances rider cadence (~80 RPM) with required pump speed
- Selected to limit rider torque while keeping effective pump operation

Motor → Wheel (12T → 35T, 2.92:1)

- Changed from 55T to increase vehicle speed
- Testing showed motor had sufficient torque, so excess torque capacity was unnecessary

Final ratio prioritizes higher speed while maintaining reliable motion

Critical Design Choices - Gearing

Chain Selection

- 9-speed (pedal side): efficient for rider input
- #35 (rear): lighter, sufficient strength after testing

Elliptical Chainring (44T)

- Smooths torque output and reduces peak rider effort

Clutch System (wire-controlled)

- Allows disengagement → reduces parasitic losses during coasting

Design Tradeoff

- Higher torque (larger sprocket) vs. higher speed (smaller sprocket)

Key Result

- Testing enabled shift toward speed, efficiency, and endurance performance



Lessons Learned



- Be aware of the parts you have and keep them organized
- Pressure building in hoses and components will apply extreme forces to mounts, so they must be properly reinforced to prevent bolt shearing and metal warping.
- Make backups of CAD model for every single step, as parts commonly corrupted if not saved properly (unfortunately learned the hard way).
- Allocate and schedule extra time to build components in the machine shop, as many times it took longer than expected to manufacture custom parts.
- Testing is critical for validation
 - Initial design overestimated required torque to move the bike





Thank You! Pump Fiction





Competition Overview

- The goal of the NFPA Fluid Powered Vehicle Challenge is to construct a fluid powered vehicle that meets the necessary requirements and to compete against other teams.
- Competition will be held on April 15th, 2026, in Ames, Iowa.
- **Team is leveraging from previous team's work product**
- There are four challenge focuses within the competition:
 - Sprint race
 - Endurance race
 - Efficiency test
 - Regenerative breaking
- **Focus:** Endurance Race and the Overall Safety of the Vehicle





Main Competition Requirements

- Vehicle propulsion must be accomplished through hydraulics with **humanpower as the prime mover**
- Must include **energy storage device**
- Must include **2 independent friction brakes**
- Must include **direct propulsion and regenerative breaking**
- Must be for a single rider who can independently enter, exit, start, and stop
- Maximum **weight of the vehicle is 210 lbs**
- All components must meet reasonable industry standards





Safety, Goals, and Broader Impact

Safety Requirements:

- System must not leak any working fluid
- Moving components must have a safety guard surrounding the element
- No pipe threading at high pressure is permitted
- No galvanized or black pipes permitted
- Hose and hose fittings must be outsourced together

Engineering Goals:

- Total Weight of the vehicle (without rider) no greater than 175 lbs
- Implementation of pneumatics
- Implement a touchscreen with friendly rider controls

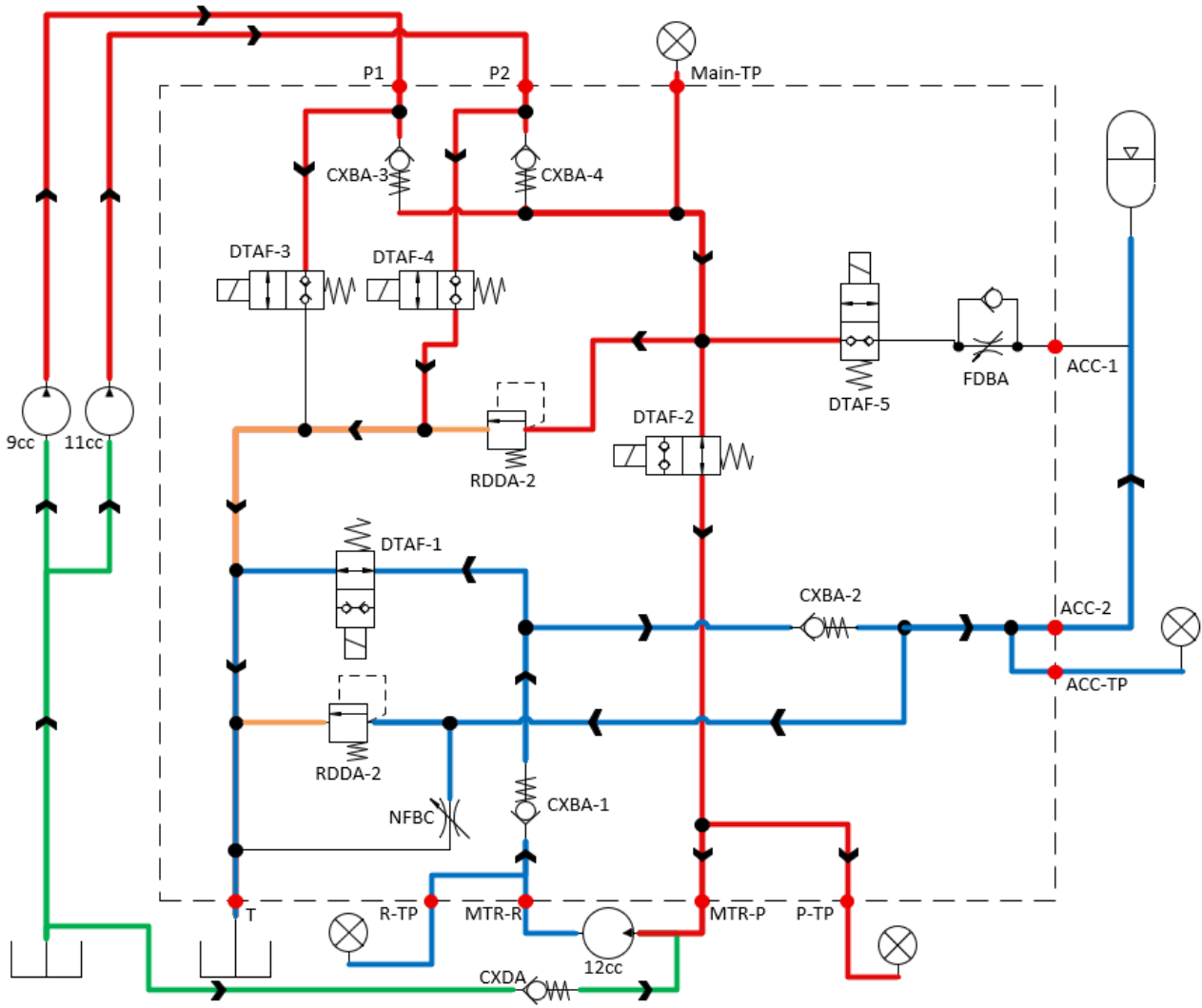
Broader Impact:

- Increase knowledge and awareness about Fluid Power and careers in this industry
- Combine fundamental fluid powered principles and known human powered mechanics to create a unique solution
- Highlight and teach teamwork, communication, and organizational skills needed as a professional engineer





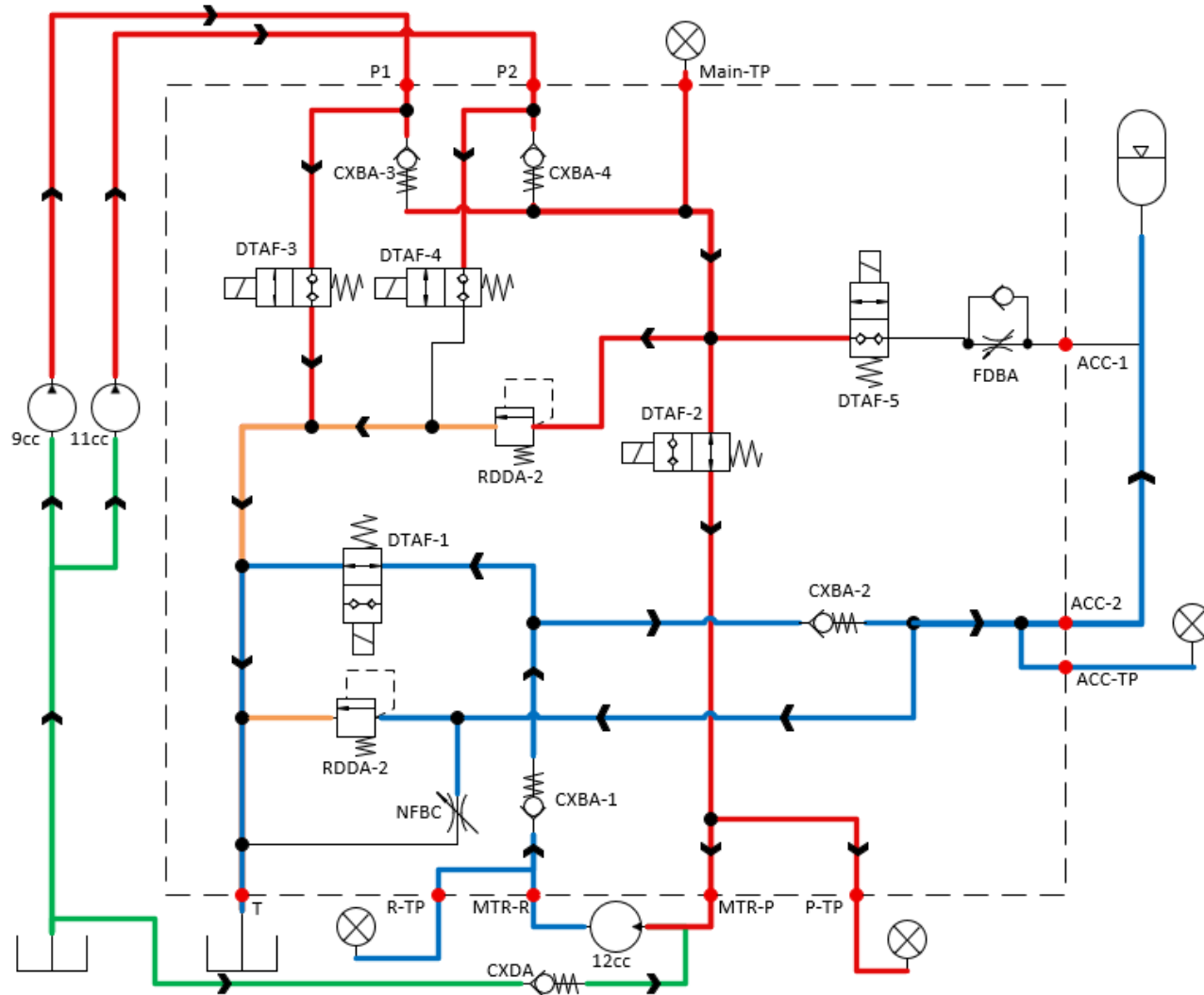
First Gear



- Inlet
- High Pressure
- Low Pressure
- Reduced Pressure



Second Gear



Inlet

High Pressure

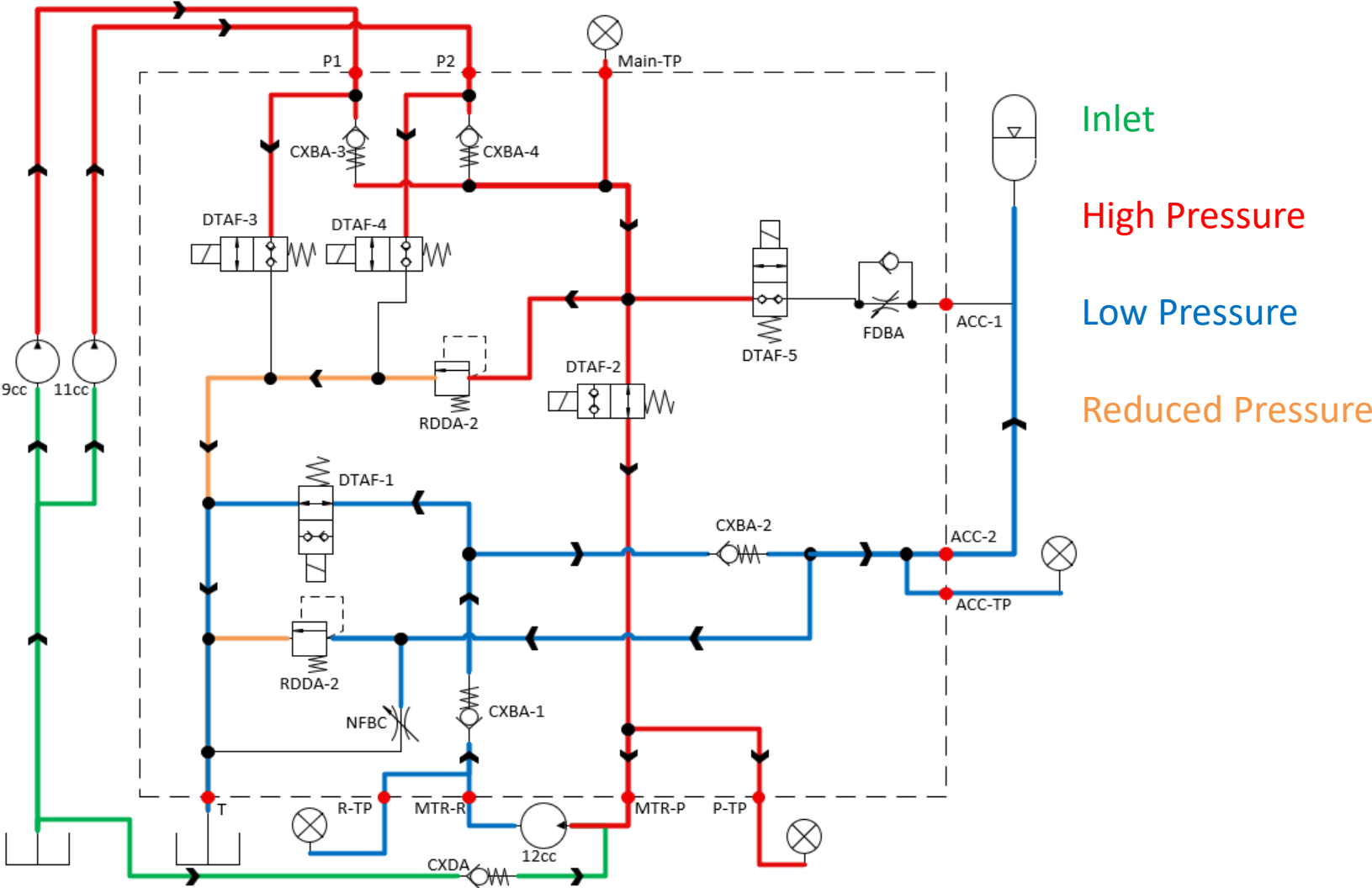
Low Pressure

Reduced Pressure



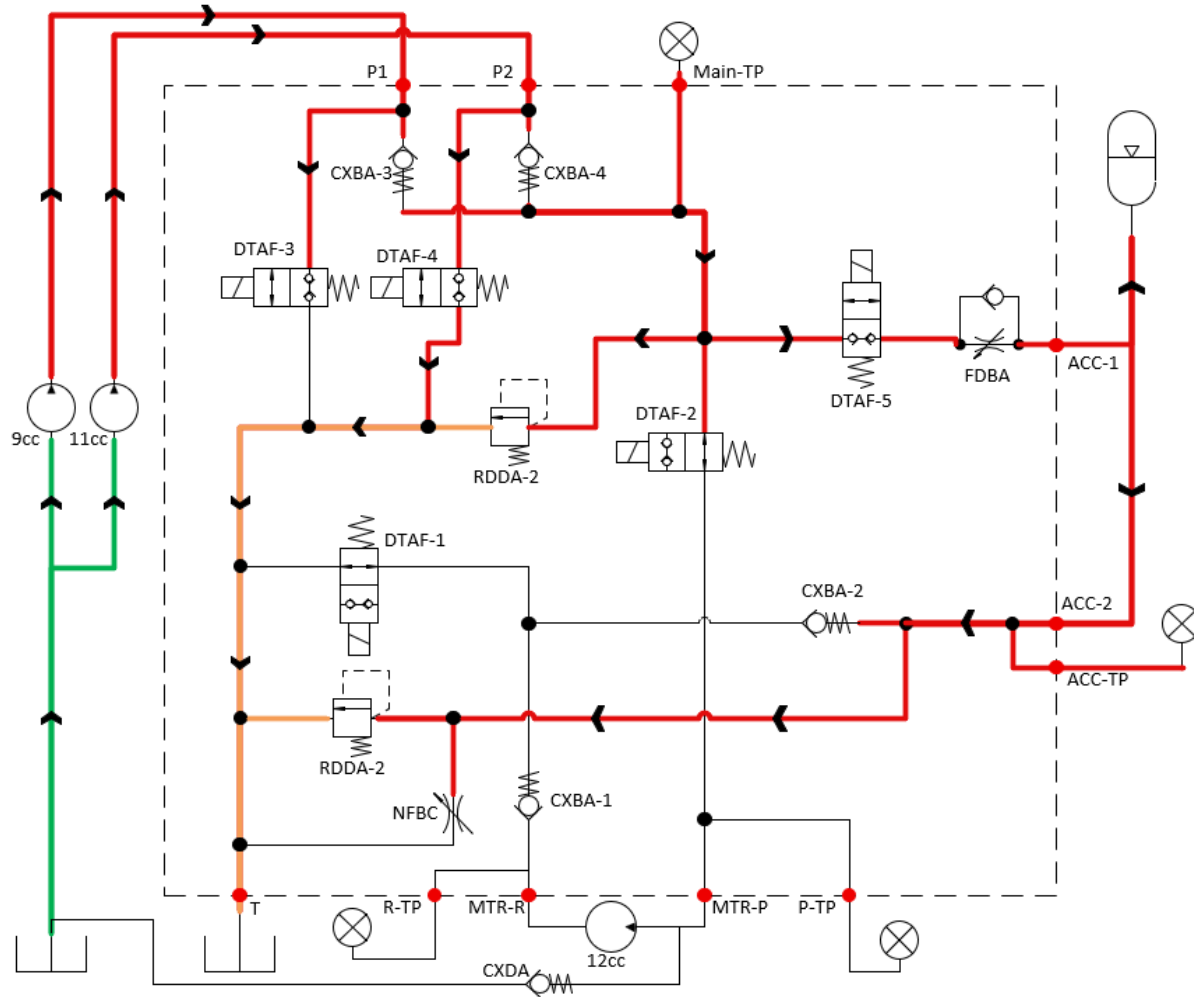


Third Gear





Accumulator Charging



Inlet

High Pressure

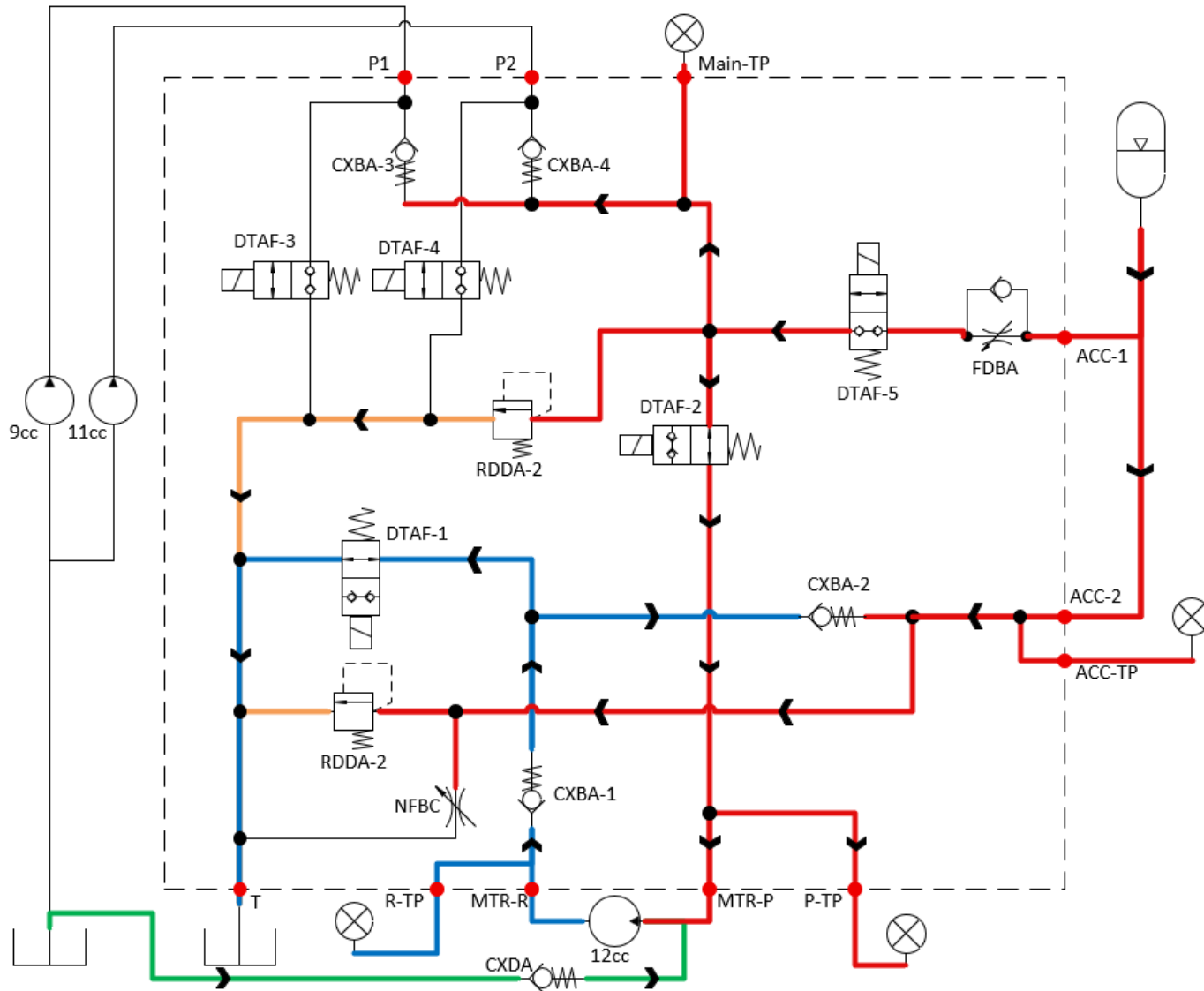
Low Pressure

Reduced Pressure





Accumulator Discharge

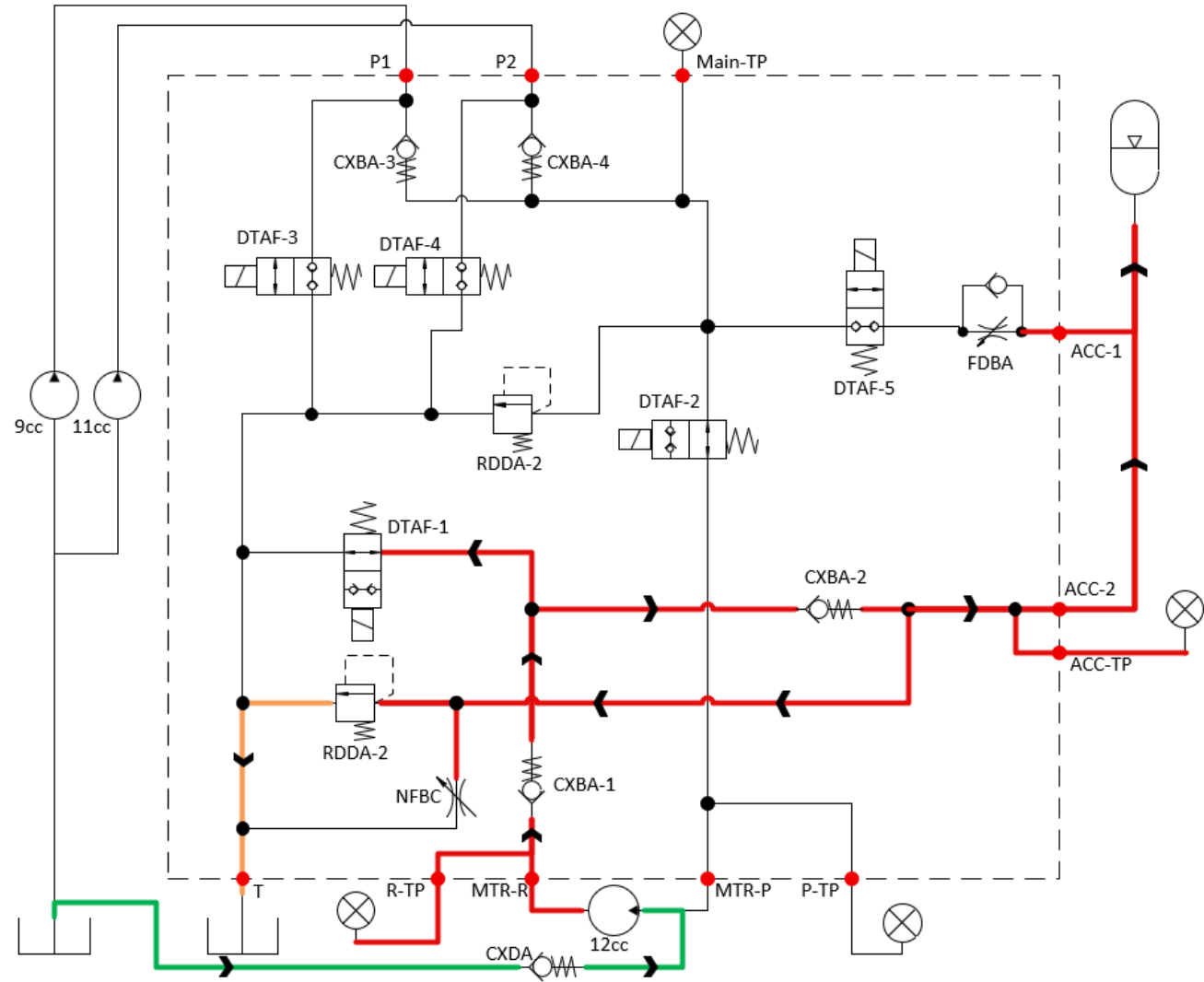


- Inlet
- High Pressure
- Low Pressure
- Reduced Pressure





Regenerative Braking

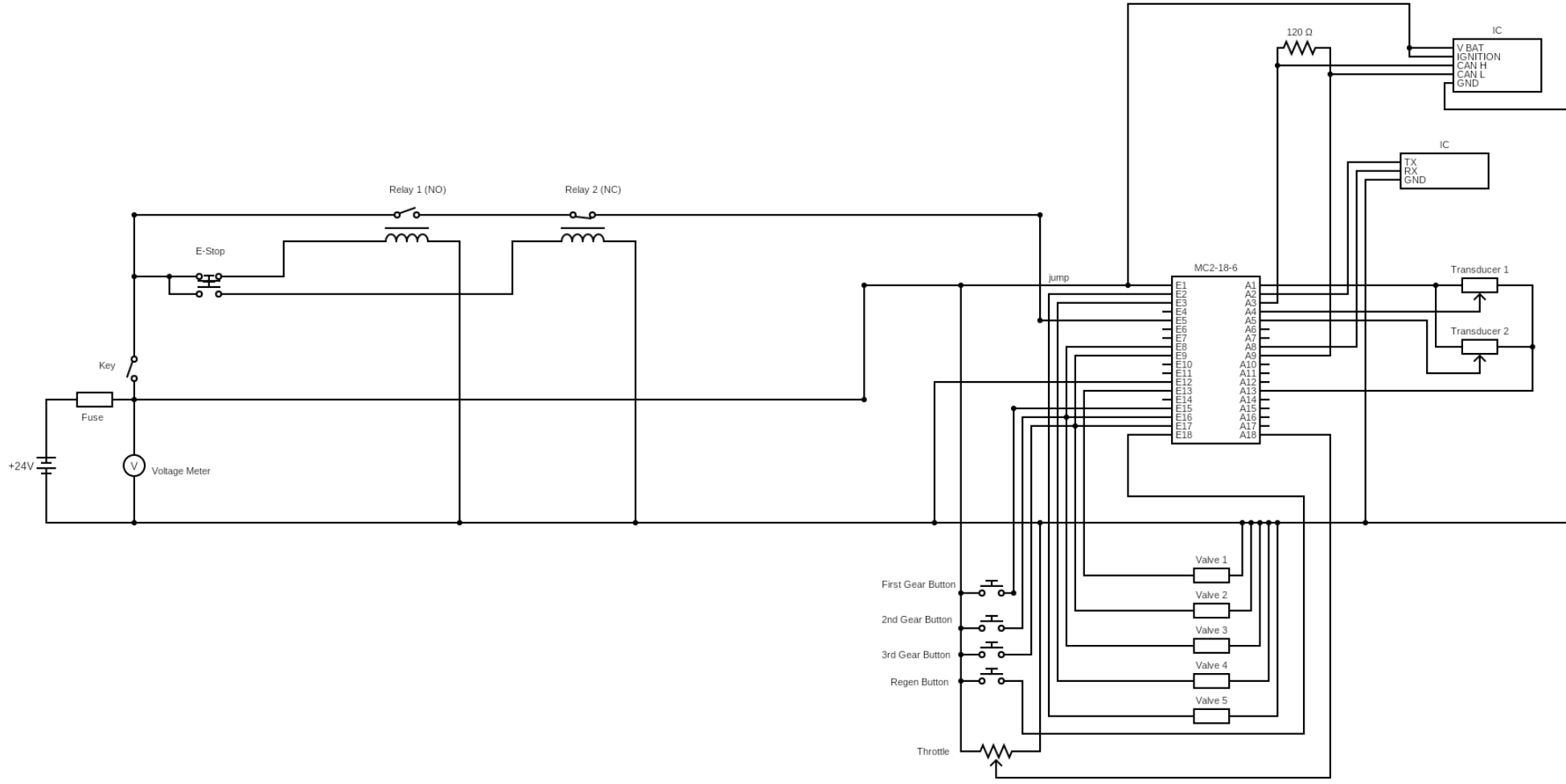


- Inlet
- High Pressure
- Low Pressure
- Reduced Pressure





Electronic Circuit





Pneumatic Confetti Cannon

- PVC plastic and solenoid valve
 - 4" PVC rated for 220 psi
 - 2" PVC rated for 280 psi

- System will operate at 25-30 psi for safety

- Mounted behind plastic shield for rider safety and pointed upward as to not hit any bystanders





Valving

- All valves from Sun Hydraulics
- Solenoid valves are direct acting poppet type
- Poppet and oversized valves used to minimize losses
- Used only 2/2 poppet valves because they are less restrictive

Drawing #	Part Number	Part Name	Cavity	Rated Flow
PV1,2,4	DTAFMCN	FLex 2W, 2P, Sol dual poppet, NC, MOR	T-8A	7 gpm
PV3,5	DTAFMHN	FLex 2W, 2P, Sol dual poppet, NO, MOR	T-8A	7 gpm
CV1-5	CXBAXAN	Free Flow Nose to Side Check Valve (4 psi)	T-162A	10 gpm
PRV1,2	RDDALAN	Direct-Act Relief Valve	T-10A	25 gpm
FCV	FDBALAN	Fully Adjust Press Comp Flow Control	T-13A	6 gpm
NV	NFBCKCN	Fully Adjustable Needle Valve	T-162A	5 gpm





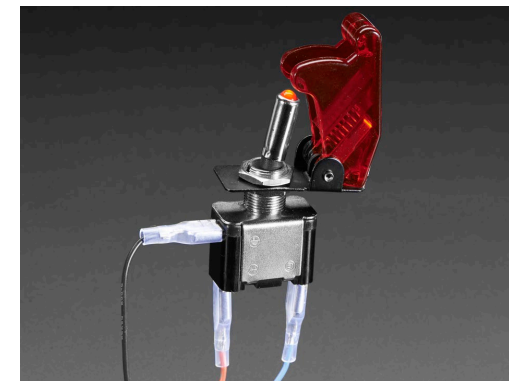
Controls Hardware

- **uControl MC2-18-6 Controller**
 - Industry standard PLC programming
 - Built in CANBUS communication channel
 - Input and Output Flexibility
- **OpenView S50 Touchscreen**
 - Built in CANBUS communication channel
 - IP65 rated
- **CODESYS Programming Environment**
 - Compatibility for both controller and touchscreen



Power Hardware

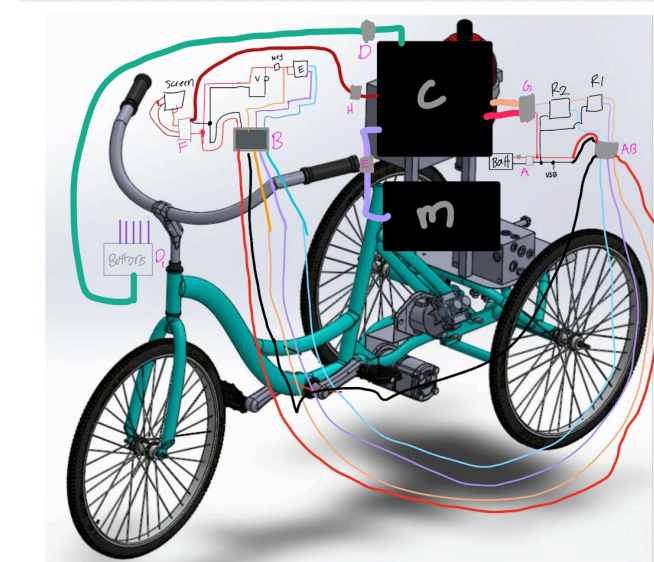
- Kobalt Tool Battery
 - Easy to charge
 - Easily swappable
- Safety Equipment
 - Voltage Relays
 - E-Stop Button
 - Fuses
- UI Components
 - Commodity switches and buttons
 - Handlebar throttle



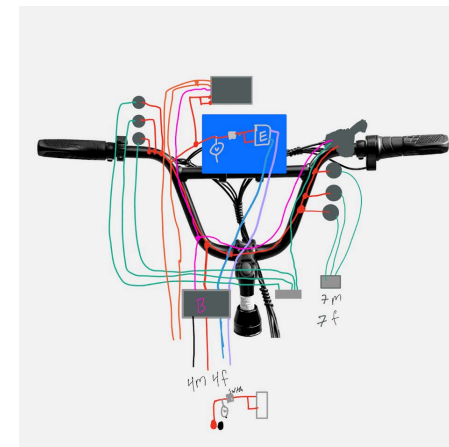
Controls Design



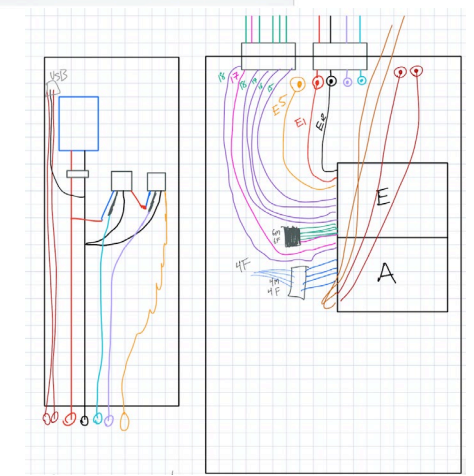
- Increased Ease of Use
 - Reduced the number of functions tied to each button
 - Important wires were specifically placed to increase ease of access for maintenance
- Created Modular Wiring
 - Added plugs at critical points for each wire run
 - Individual wire runs can be completely removed for ease of travel and maintenance
- Added Redundancy
 - Used both screen and physical buttons to control drive modes
 - Added buttons on screen to individually actuate specific valves



Initial wire plan drawing



UI wire plan drawing



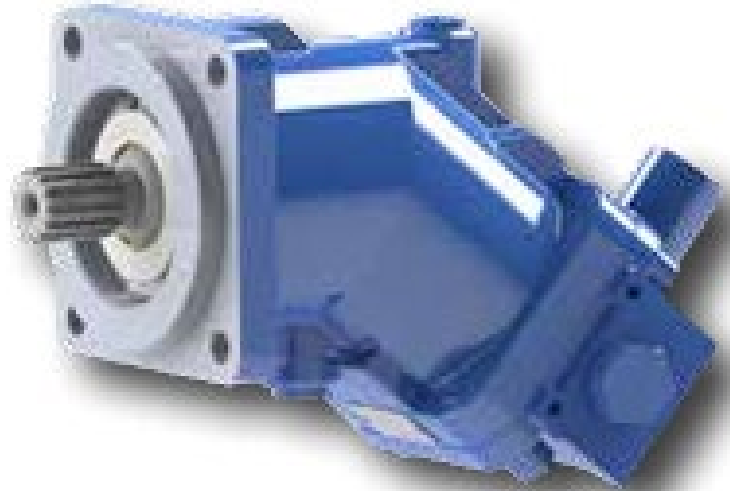
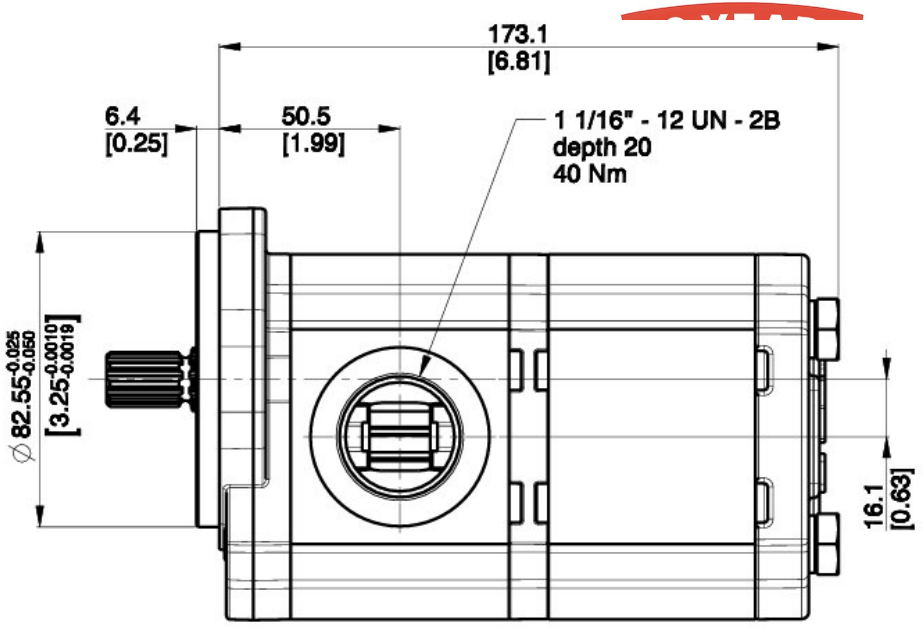
Power and controller wire plan drawing



Pump and Motor

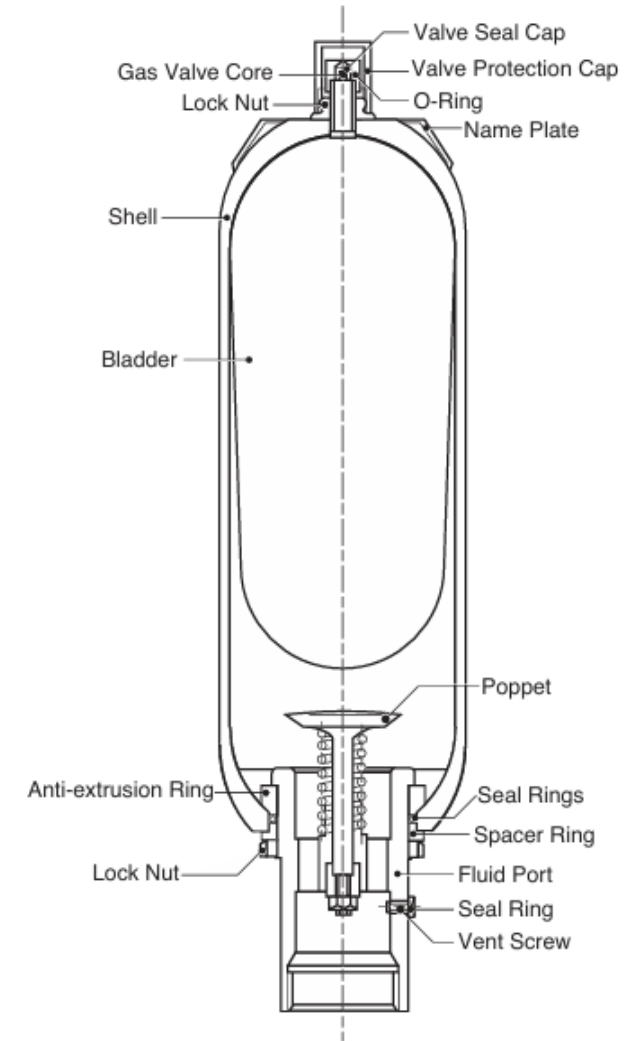
- Pump
 - Casappa Dual-Outlet Gear Pump
 - 9cc and 11cc outlets
 - Will reduce rider fatigue

- Motor
 - Hydro Leduc MA Series Hydraulic Motor
 - MA 012 C S1 P0 U2 0 0 SV F SP



Accumulator

- Purpose
 - Pre-charge the system
 - Supply short bursts of peak flow
 - Capture braking energy by recycling fluid
- Reuse the accumulator from last year's team
 - SB330-4A1/112S-210C
 - One gallon
 - Max Flow: 160GPM
 - Reduce overall cost, risk, and lead time
- Mounted vertically and shielded during use to protect the rider



Gearing

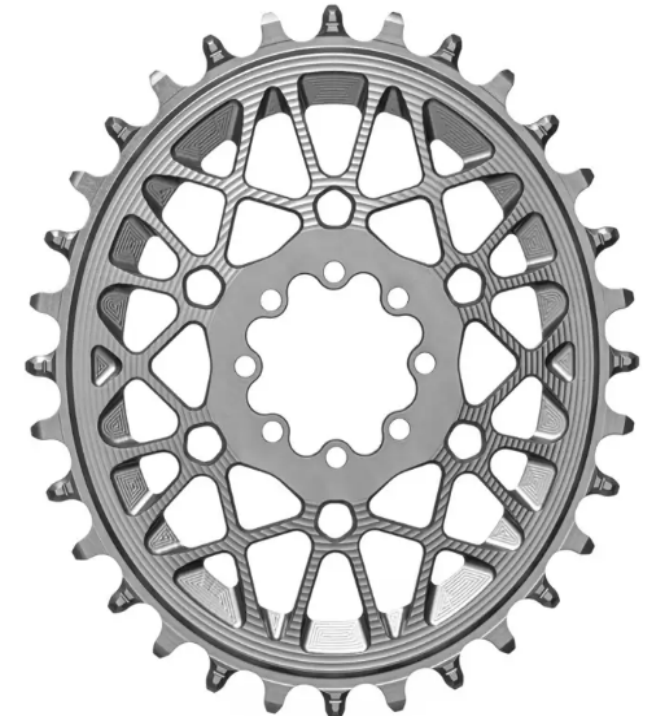
Chain and gear system selected:

- transmit power from the crank to the hydraulic pump
- Transmit power from hydraulic motor to rear axle
- Reliable
- Efficient torque transfer

Implementation of oval crank gear:

- Variable effective gear ratio throughout the pedal stroke
- Improve cadence consistency
- Reduce rider fatigue
- Makes low pressure pedaling more intuitive

10 YEARS

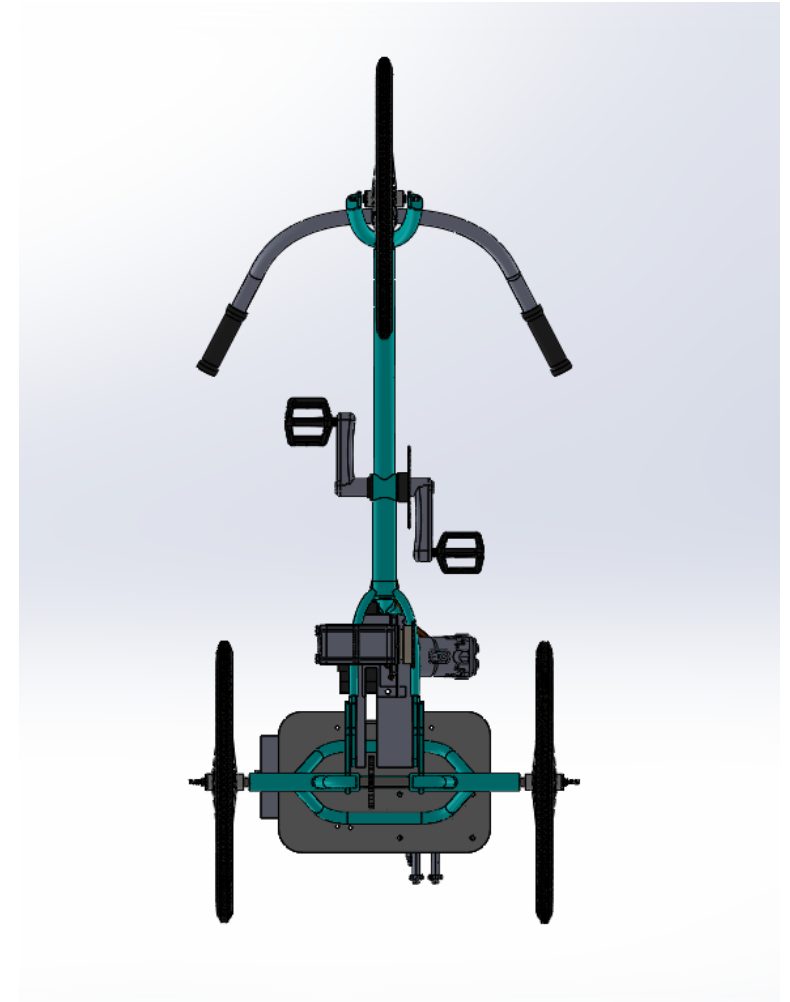
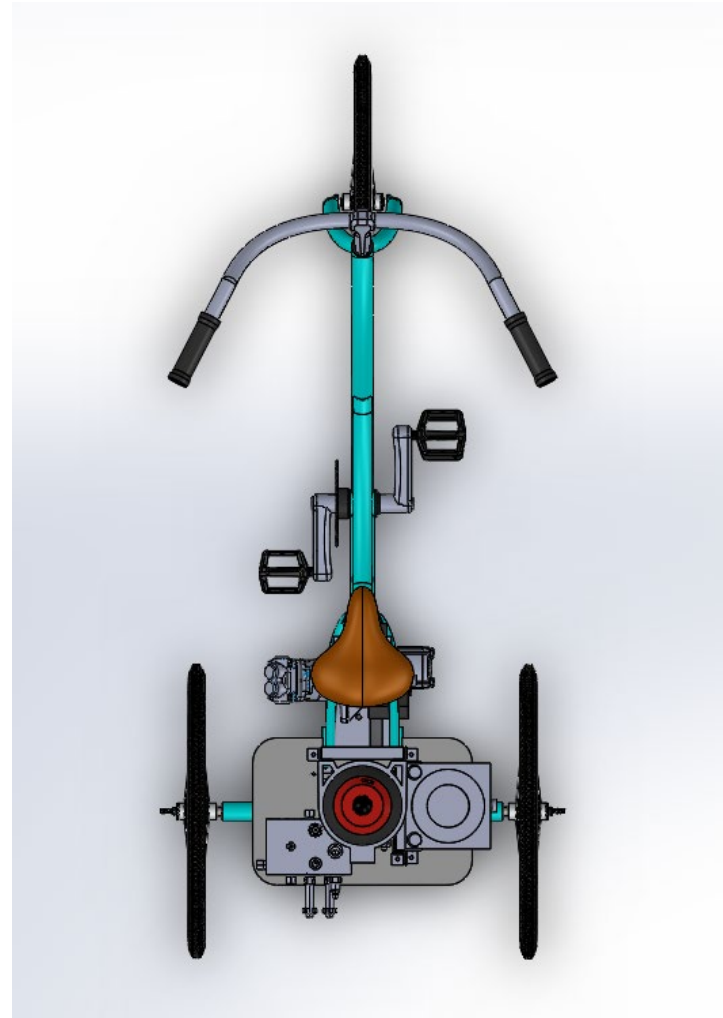
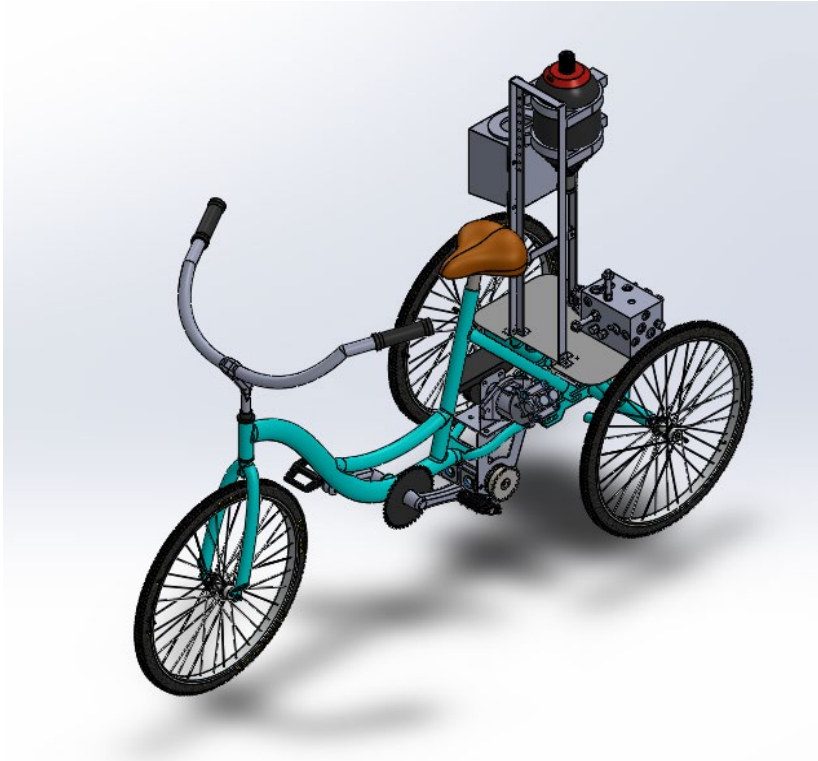


Drive Train Components

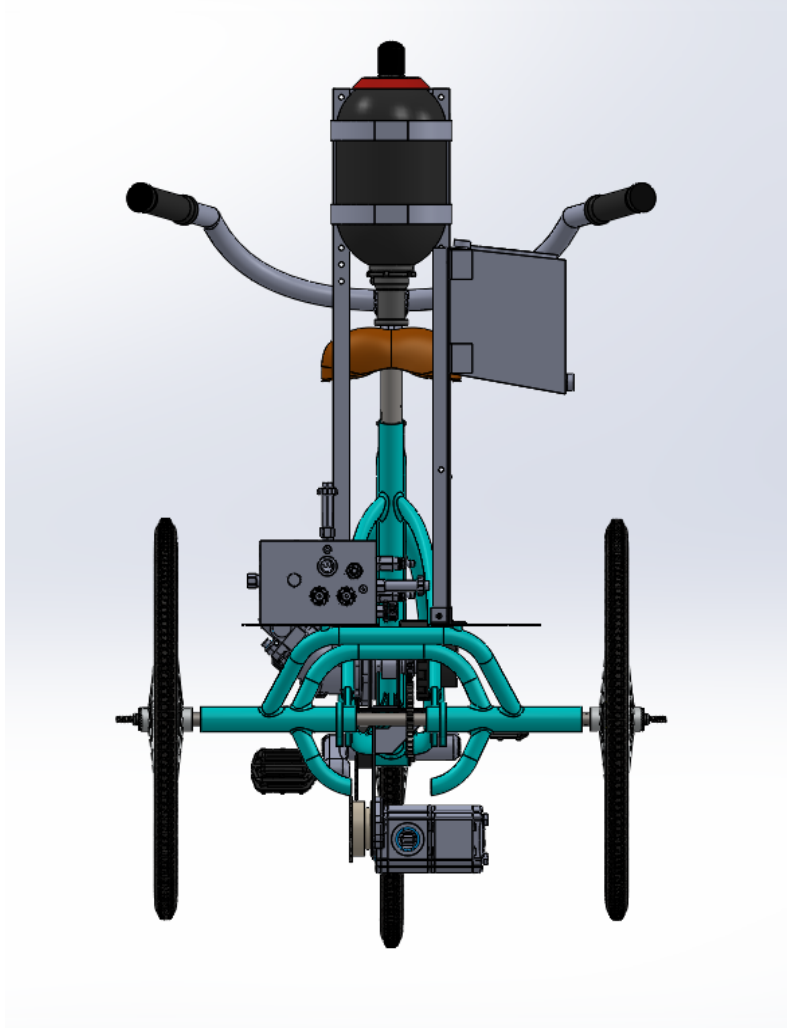
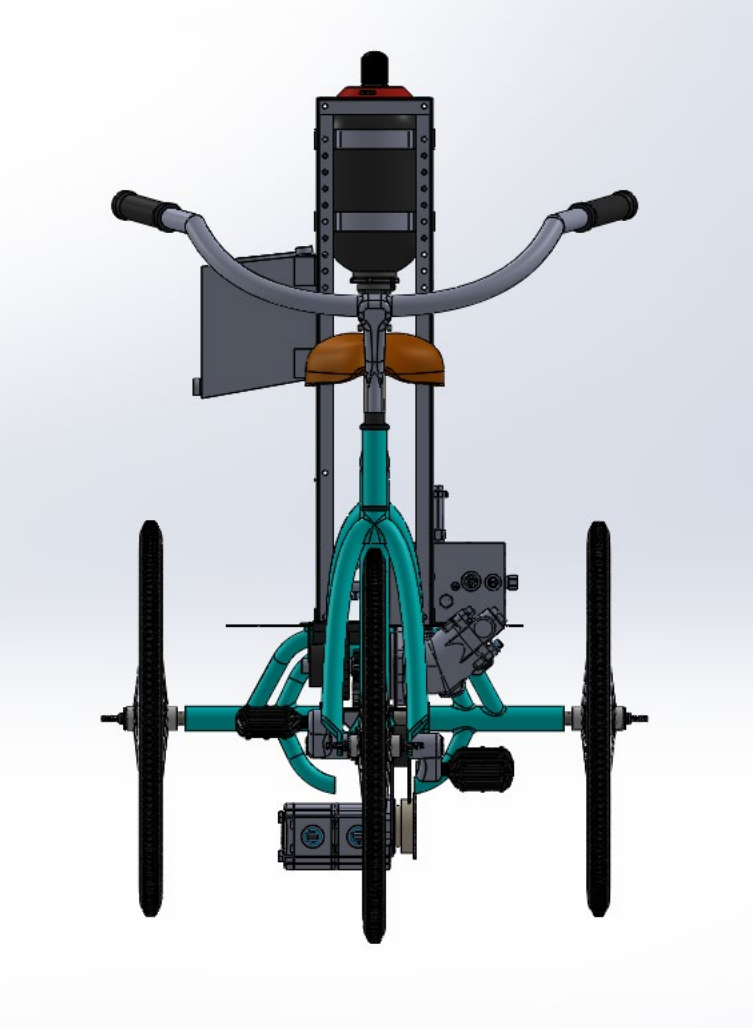
- Cable Actuated Clutch
 - Allows rider to manually disengage the hydraulic motor from the rear axle
 - Enables free coasting without back-driving the motor
 - Improves efficiency when disengaged
- Oval Gear at Crank
 - Provides variable effective gear ratio through pedal stroke
 - Reduces peak rider torque demand
 - Improves pedaling smoothness
- Standard Bicycle Gearing Components
 - Remaining drivetrain uses conventional circular chainrings, sprockets, and chains
 - Simplifies integration, maintenance, tunability, and reliability



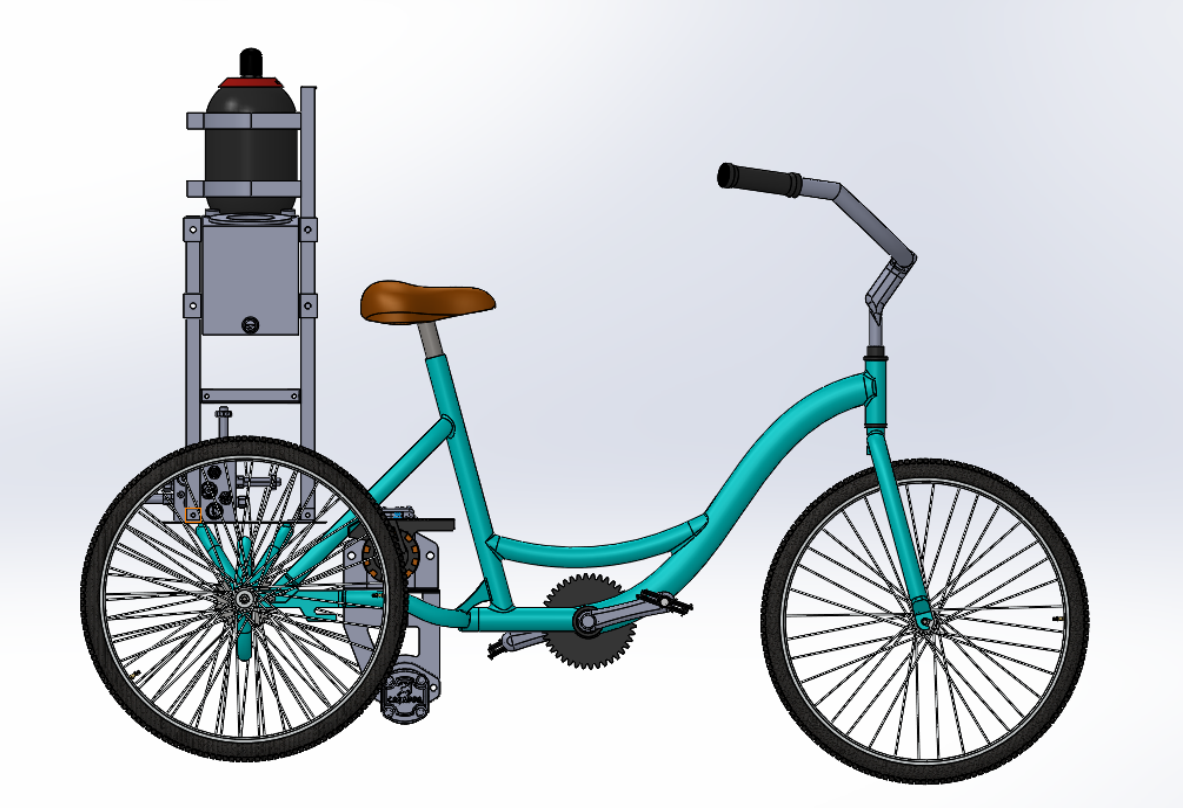
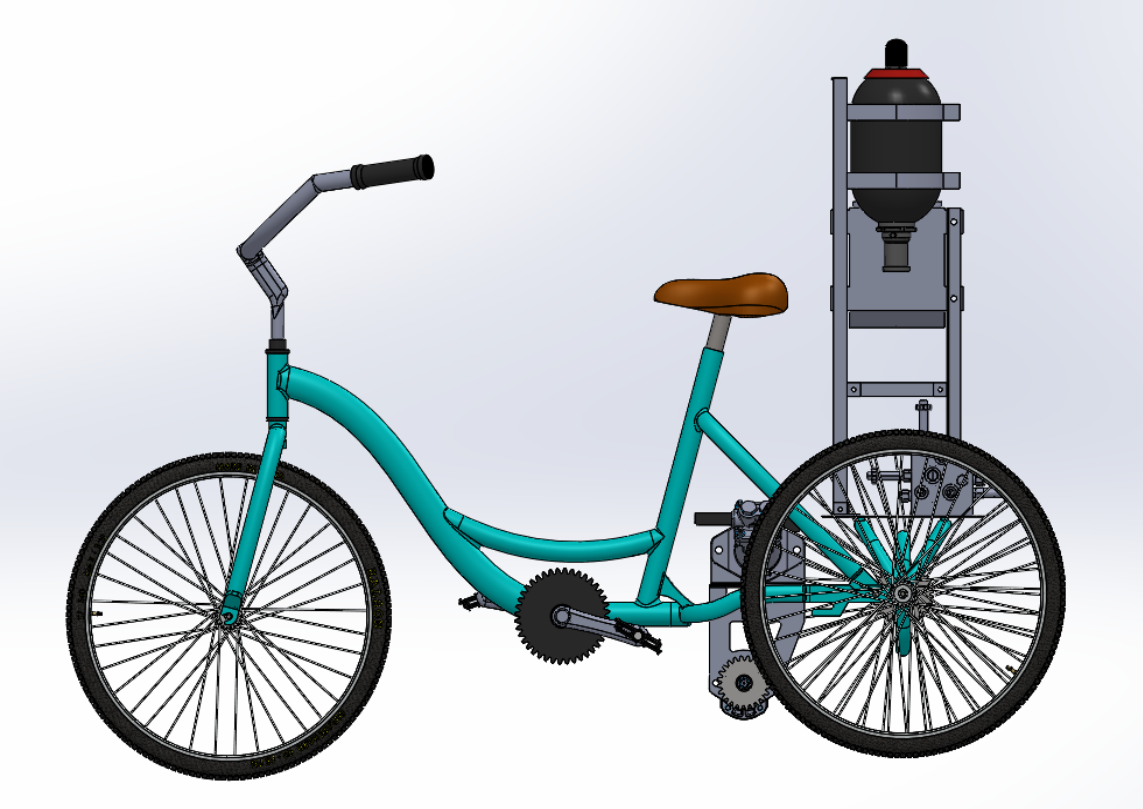
Isometric, Top, and Bottom View



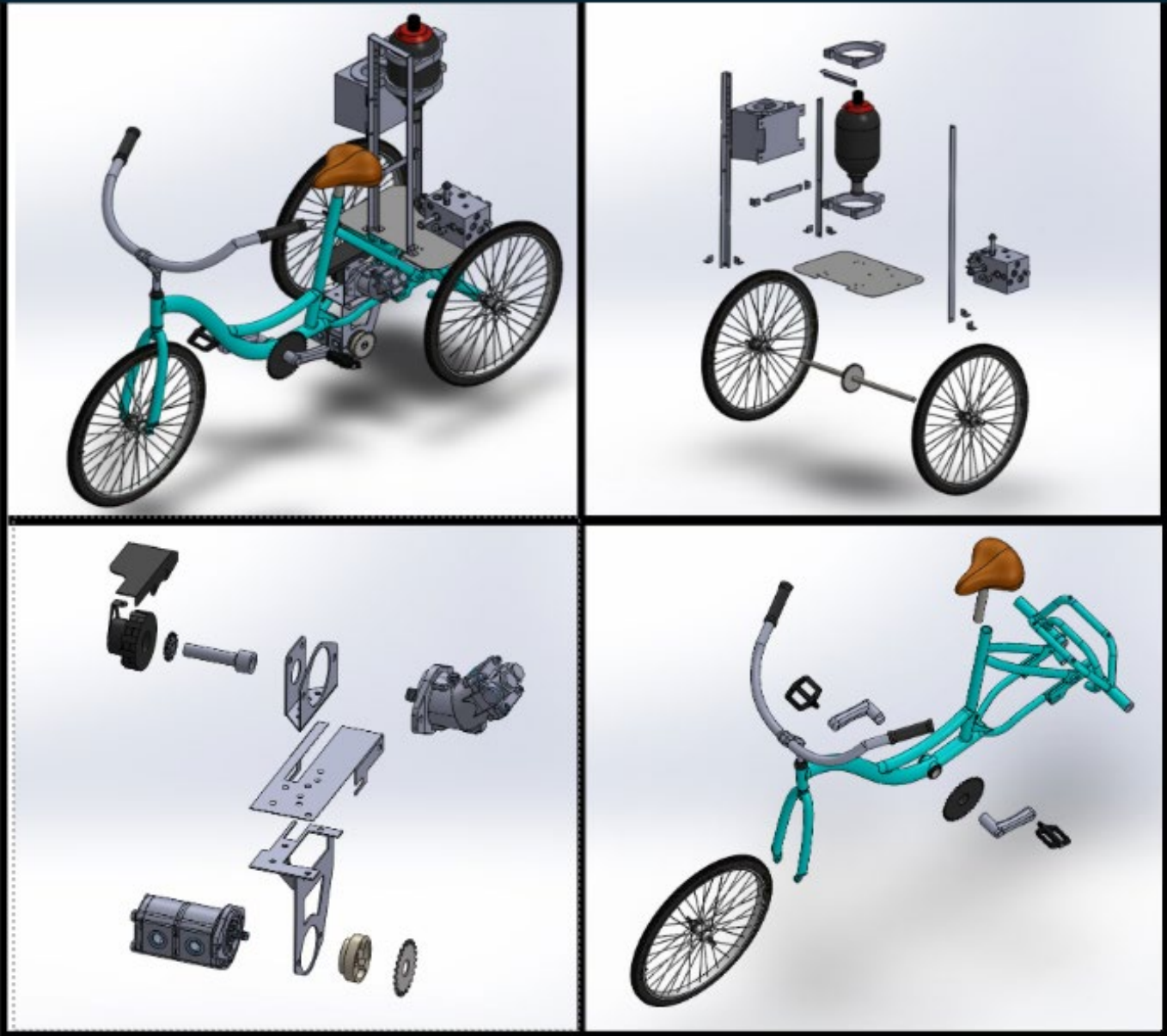
Front and Back View



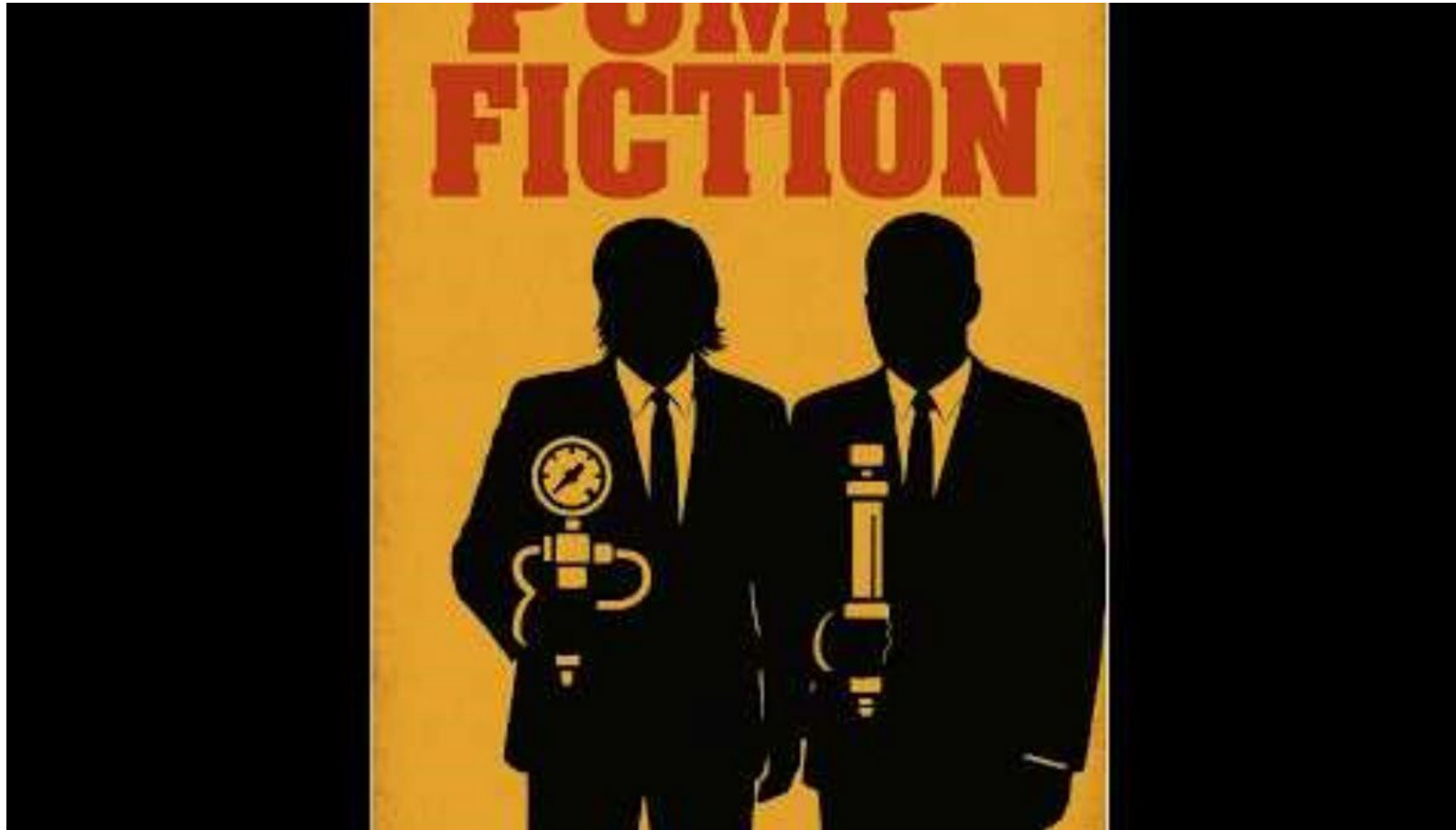
Side Views



Exploded View



Proof of Working Vehicle 1



https://youtu.be/JG2S_j75aFU

Proof of Working Vehicle 2

