NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

FINAL PRESENTATION
UNIVERSITY OF AKRON
DR. SCOTT SAWYER & TODD STYER
4-13-23

AKRON

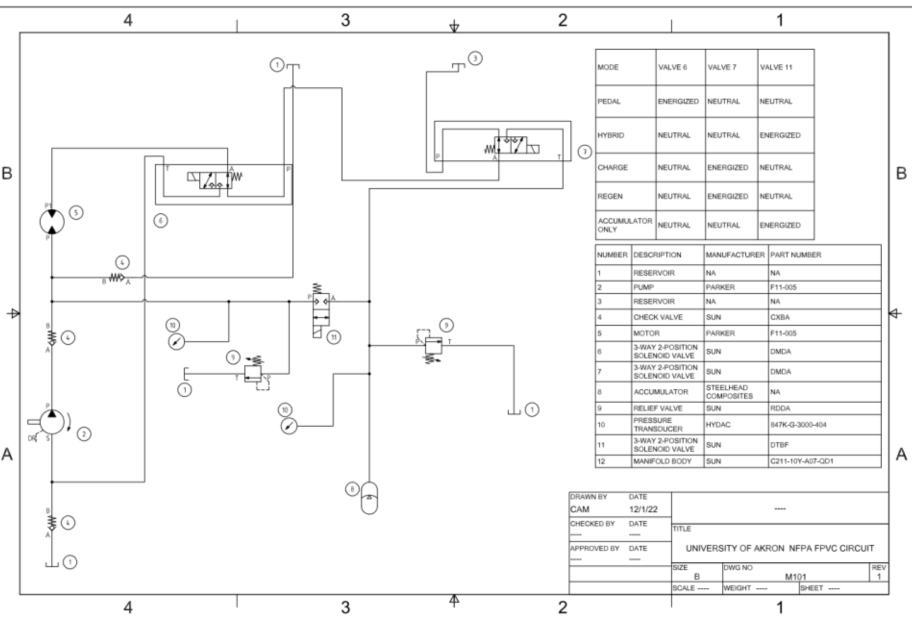
TEAM INTRODUCTION

- Team Members: Ethan Andrews, Carter Moore, Andrew Sobel, Bryce Towne
- All fifth-year Mechanical Engineering students at the University of Akron

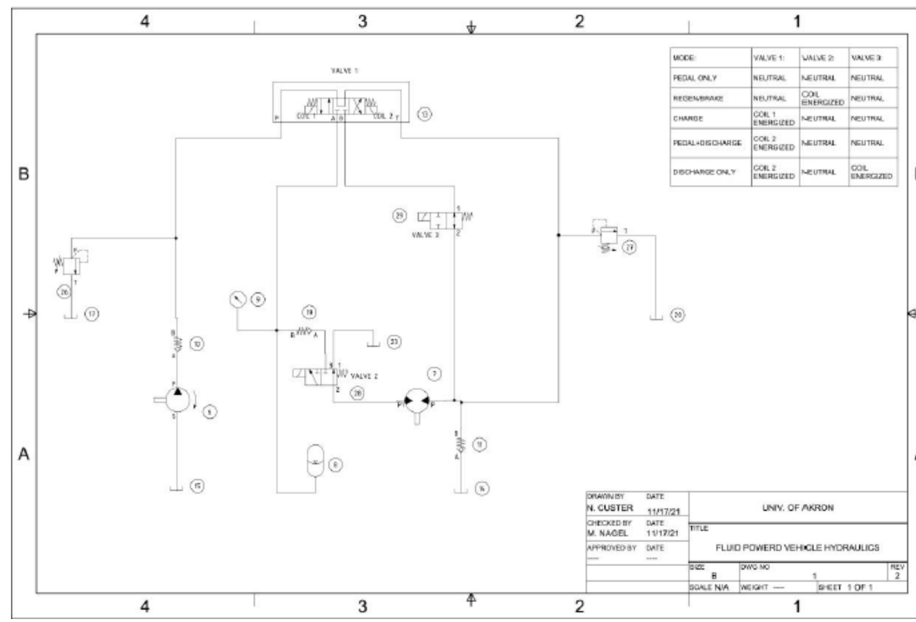
From Left to Right: Ethan Andrews, Andrew Sobel, Bryce Towne, Carter Moore

Circuit Improvements

- Circuit from last year’s team was completely redesigned to include a “closed loop” feature that directly connects pump/motor without going through the reservoir and puts valves after motor (different valves used)



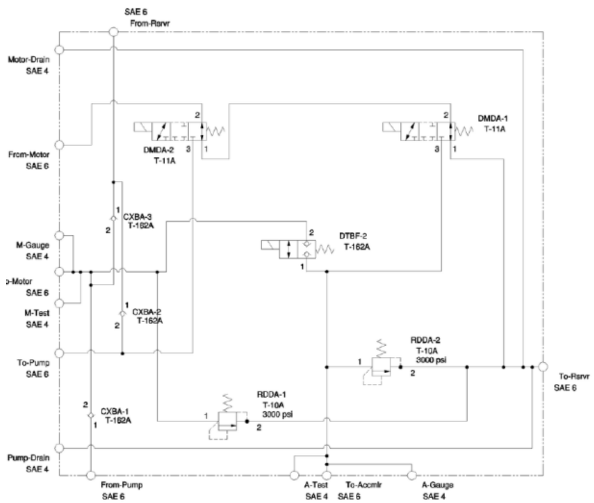
Our Circuit

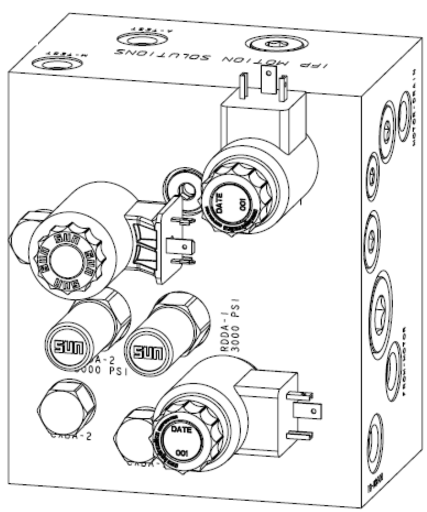


Last Year’s Circuit

Manifold Design/ Build

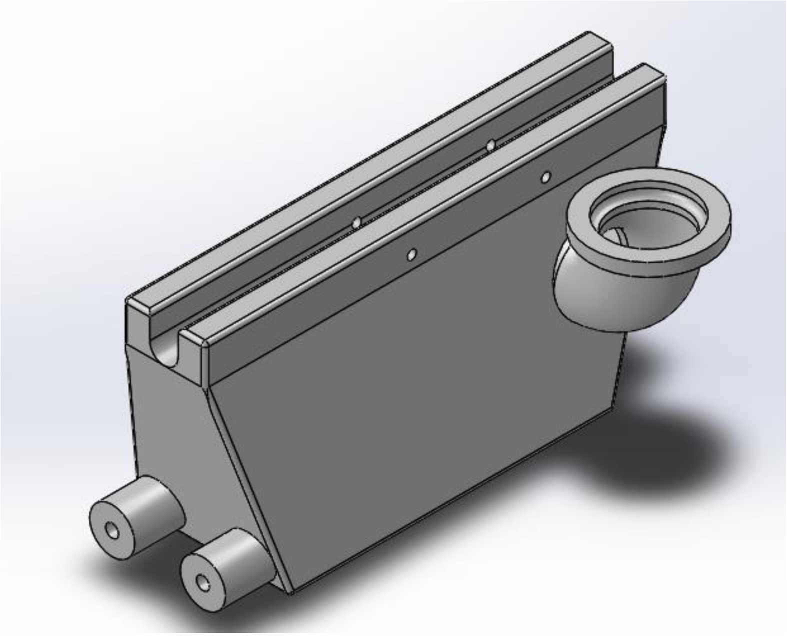
- Custom manifold designed/manufactured with logical port placement





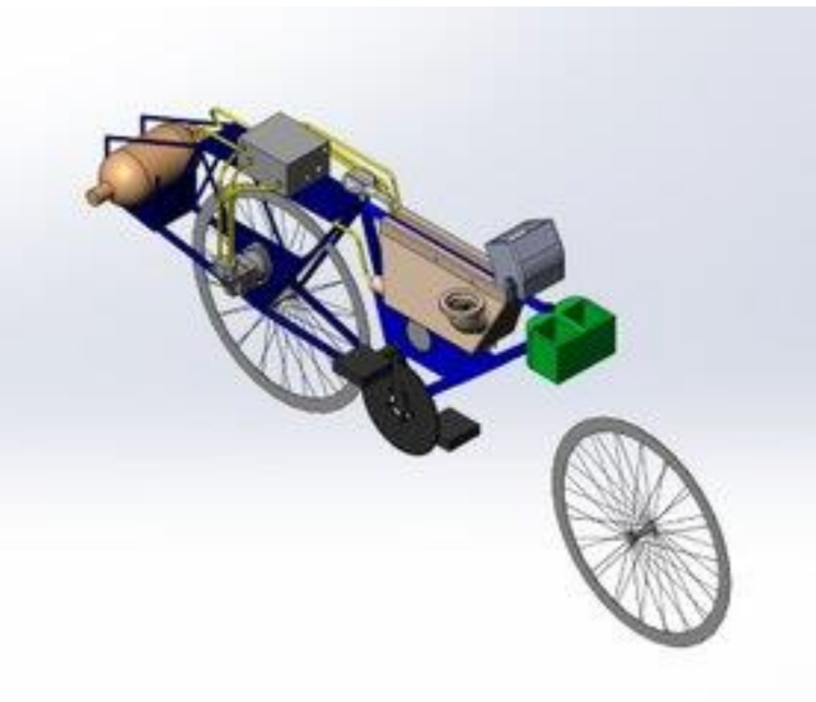
Reservoir Design/ Build

- Reservoir designed, 3D-printed (externally), and then sealed with por15 and epoxy



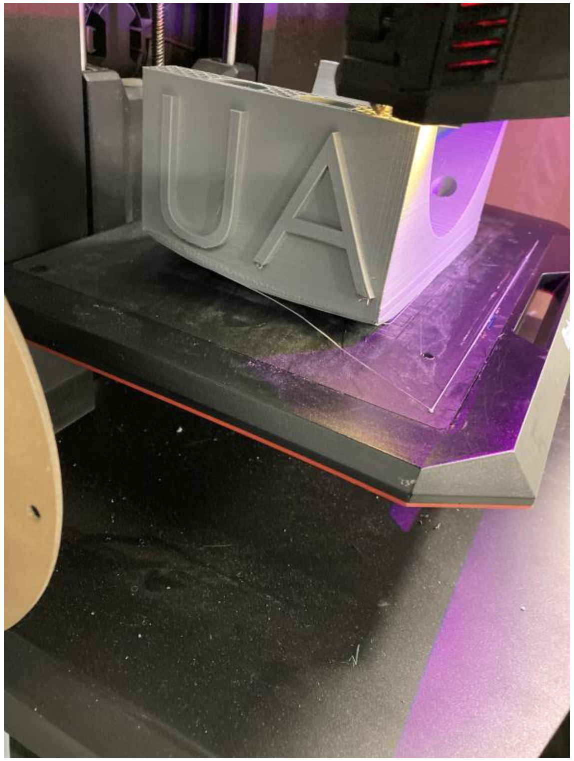
Mounting Frame Design/ Build

- New aluminum frame for mounting components using angle-iron was designed in Solidworks and then welded by us at Akron
  - Holds motor, manifold, and accumulator



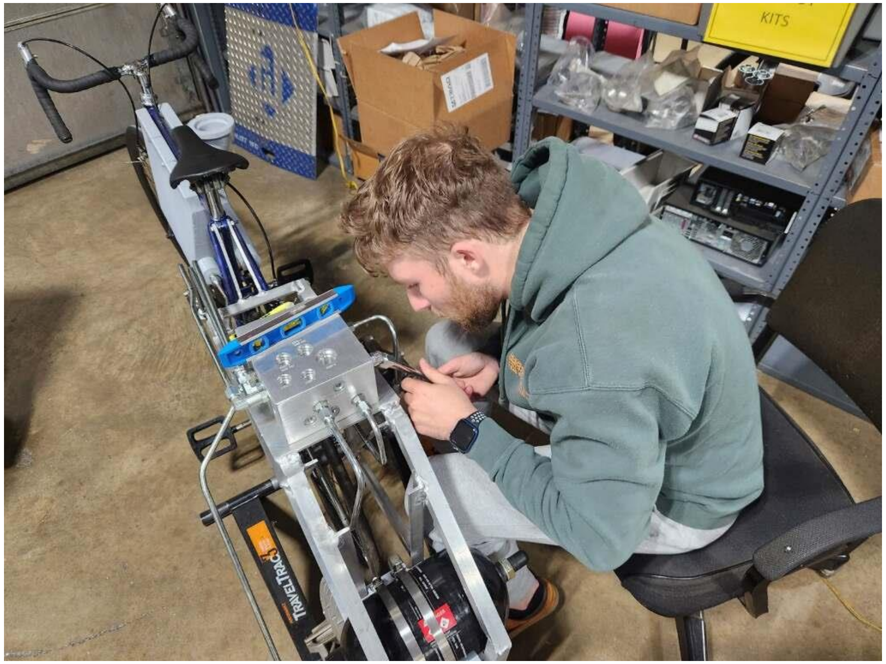
3D-prints

- Components that were designed and 3D-printed in our lab include the controller holder, battery holder, and the accumulator holder



Hard-Lining

- All hard-lining was done by us at Triad Technologies, who generously allowed us to work there and use their flare fitting tool
  - Hard-lining was done with 5000 psi rated piping (3/8” x .065)



Vehicle Testing/ Safety

NFPA Fluid Power Vehicle Challenge

- Fluid was placed in the reservoir and then left overnight with paper towels underneath to detect any leak in the system
- Once no leak was detected, we tested on the stand and monitored pressure readings
- Our mentor, Todd Styer, was present to help us set relief valves to just under 3000 psi
- We also added fall protection to the frame to protect the hard-lines incase the bike tipped over

Vehicle Testing/ Safety

NFPA Fluid Power Vehicle Challenge

- After initial testing, we went with a lower accumulator pre-charge, filled the tires to higher pressure, raised the motor to tighten the chain and used Loctite on the set-screw to keep it from slipping
- Additionally, we monitored pressure from test port and pressure transducers to set reliefs

Vehicle Testing/ Safety

NFPA Fluid Power VEHICLE Challenge

- After simulating the competitions races and verifying that all modes worked, we rigorously inspected the bike to ensure all bolts were still tight and nothing was unsafe.

Vehicle Testing/ Verification

- Calculations were run again based off real data (approximate rpm we were running the motor during pedal)
- Calculations matched fairly closely to ones with assumptions

- $n\ (rpm) = 4\ (gear\ ratio) * 50\ (pedal\ rpm) = 200$
- $q\ (\frac{l}{\min}) = \frac{4.9\,\frac{cm^3}{rev}\,x\ 200\ rpm}{1000 * .8} = 1.23\ l/\min = 0.324\ gpm$
- $\Delta p\ (bar) = \frac{63 * 11.75\ Nm}{4.9\frac{cm^3}{rev} * .8} = 120.85\ bar = 1754\ psi$

Testing Results

- Sprint race:
  - 500 feet in 37 seconds
- Endurance race:
  - 3.25 miles in 15 minutes
- Regen race
  - 150 feet regening with accumulator charged to 800 psi rolling down hill
- Efficiency race:
  - Able to go around 2000 feet on a pre-charge near 2900 psi

Final Product

- Our final product achieved our goals:
  - Making the bike more ergonomically friendly/ easier to pedal
  - Reducing weight
  - Safe operation
  - Using electronic controls
  - Designing a new circuit and manifold
  - Having rider see pressure gauges

Design Choices

- The choice to use a “closed-loop” feature between the pump and motor made pedaling significantly easier and reduced time to get pressure when pedaling.
  - This is evidenced by the different rides when using the two “pedal only” modes
  - Consequence of this is increased backpressure on motor since going through valves on the low-pressure side (low flow rates made this acceptable to us)
- Balancing reservoir with the frame in the back helped more evenly distribute weight for easier ride
- Using a manifold helped organize all valving
- Using hard-lining should have reduced some of the losses in the piping to get a little more head than if we had used hoses
  - Hard-lining is also slightly safer and has limited deformation under load

Lessons Learned

- Communication is key to achieving success
  - Had to communicate with vendors (Triad/IFP) to get what we wanted
  - Had to communicate as a team effectively to talk through difficult design choices
- Hydraulics are very powerful and useful for storing energy
  - This is evidenced by the long distances we are able to achieve when charging and discharging the accumulator
- Designs may not always go exactly to plan and have to improvise and adapt to imperfect conditions
- Technical Skills:
  - Andrew learned how to weld
  - Andrew, Ethan, and Bryce learned how to hard-line
  - Carter improved 3D-printing abilities
  - Everyone learned how to read/design hydraulic circuits
  - Andrew and Bryce learned how to use controller
  - Carter and Ethan improved Solidworks (CAD) skills

Thank You to All Who've Helped

- Advisors: Dr. Scott Sawyer & Todd Styer
- Competition Organizer: NFPA
- Competition Sponsors: Norgren, IFP, Sun Hydraulics, Lubrizol, Danfoss, SunSource, Parker Hannafin
- Companies who've helped us: Schmidt Proto, Triad Technologies
- Individuals: Mary Pluta, Ernie Parker, Stephanie Scaccianoce, Josh Scarbrough