NFPA

Fluid Power VEHICLE Challenge

NFPA Education and Technology Foundation

UNIVERSITY OF CINCINNATI
FINAL PRESENTATION
DR. MUTHAR AL-UBAIDI
APRIL 2022

Agenda

- Team Introductions
- Project Goals/Objectives
- Design Recap
- Midway Summary
- Results/Analysis
- Lessons Learned
- Questions

Team Introductions

Ian Gilbertsen

- Positions
  - Team Lead
  - Hydraulic Circuit Lead
  - Fluid Power Club President

- Hometown
  - Powell, Ohio

- Education & Work Experience
  - 5th year, University of Cincinnati
  - Mechanical Engineering Technology
  - 5 co-op rotations
    - GE Appliances
    - Goodyear Tires

- Interests
  - Watching sports and movies
  - Spending time with friends and family
  - Hiking, camping, Fishing
  - Video games

Brandon Walsh

- Positions
  - Controls Lead
  - Treasurer

- Hometown
  - Fort Thomas, Kentucky.

- Education & Work Experience
  - I am a 5th year Mechanical Engineering & Technology student at University of Cincinnati
  - Completed one co-op with PEDCO Engineering and Architecture in Sharonville, Ohio
  - Completed four co-ops with the United States Playing Card Co in Erlanger, Kentucky
  - Completed one co-op with Integrated Test and Measurement in Milford, Ohio

- Interests
  - Camping, hiking, kayaking, and caving
  - Working around my family's farm

Zachary Selby

- Positions
  - I worked on the Frame, Pneumatics, and Gearing, with contributions to the Hydraulics

- Hometown
  - Newark, Ohio

- Education & Work Experience
  - I am a 5th year mechanical engineering and technology student at the university of Cincinnati
  - I have co-oped for 4 terms, two terms at Vertiv, and two terms at Emerson Climate Technolgies

- Interests
  - I enjoy playing disc golf and working out in my free time

Kirk Stephenson

- Positions
  - I worked on the Frame fabrication, Pneumatics, and Hydraulics

- Hometown
  - Cincinnati, Ohio
- Education & Work Experience
  - I am a 5th year mechanical engineering technology student at the university of Cincinnati
  - I have 4 Coop experiences, 1 terms at Makino as an Application engineering Coop, and 3 terms at Emerson Climate Control as a refrigeration engineering Coop
- Interests
  - Hunting, fishing, and disc golf
  - Work interests: Manufacturing and project engineering

Nathan Blickensderfer

- Positions:
  - Frame Design
  - Fabrication Lead

- Hometown
  - Columbus, Ohio

- Education & Work Experience
  - 5th year, Mechanical Engineering & Technology student at University of Cincinnati
  - Completed first two co-ops with Modine Manufacturing up in Racine, Wisconsin
  - Completed last three co-ops with David J. Joseph Company down in Cincinnati, Ohio

- Interests
  - Traveling (experiencing new places)
  - Watching sports with friends and family
  - Hiking, Kayaking, Camping, lots of outdoor Activities

Muthar Al-Ubaidi, PhD

- **Professor and Director Mechanical Engineering Technology Program**
- **Education**
  - B.S. Mechanical Engineering, University of Baghdad
  - Masters Nuclear Engineering, University of London
  - PhD Nuclear Engineering, University of Cincinnati
- **Hometown**
  - Baghdad, Iraq
  - Came to Cincinnati, USA in 1978
- **Project Team**
  - Faculty Advisor

Industry Mentor

NFPA Fluid Power Vehicle Challenge

Assigned Mentor

- Dan Turner of GPM Controls
  - Hydraulic expert
  - Reviewed calculations
  - Offered opinions and input
  - Assisted with concept creation

GPM Controls

Don't just go with the flow... Control it!

Goals/Objectives

Goals/Objectives

Competition Goals

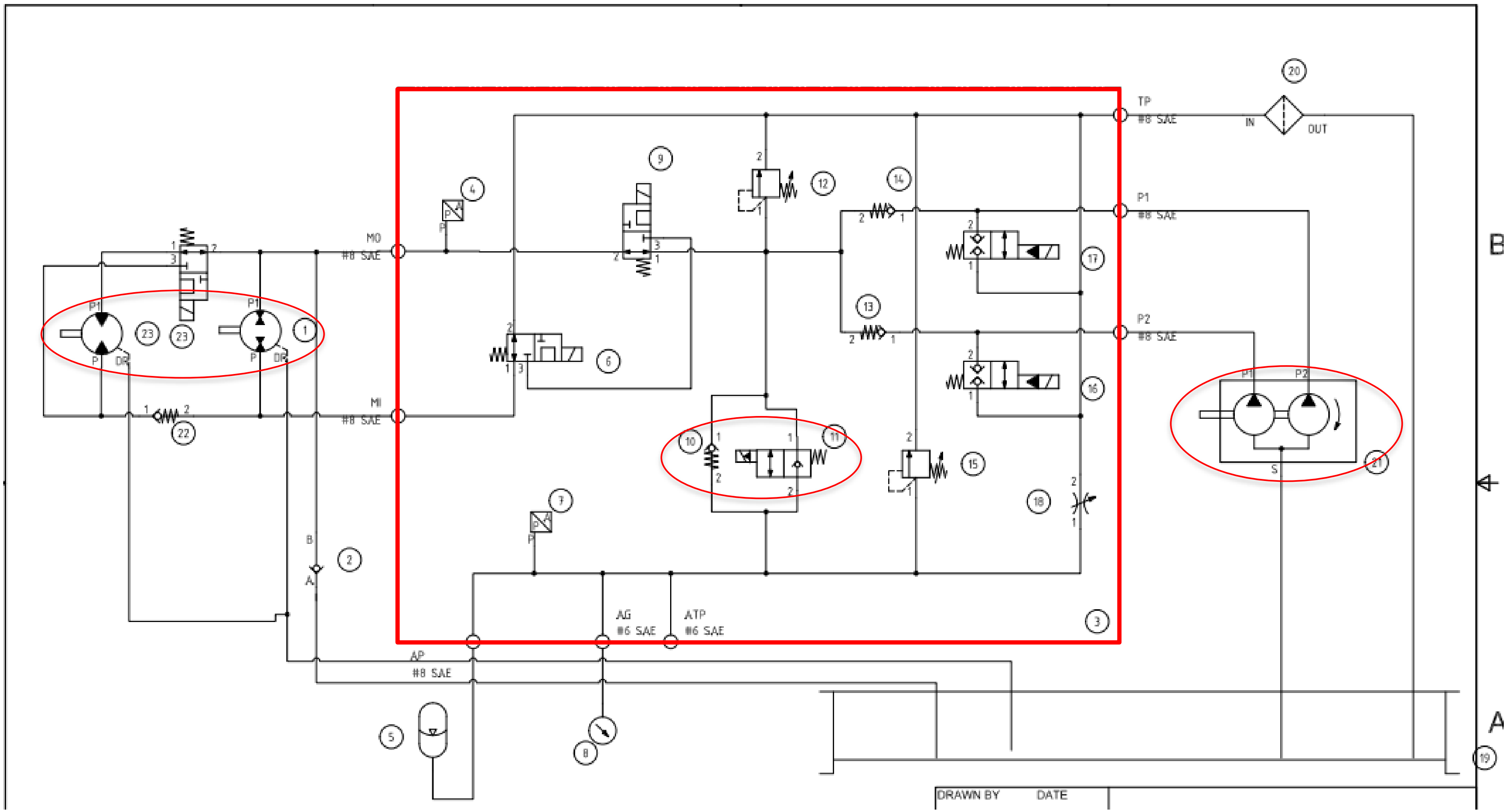
- Create vehicle that will travel 400-600 ft in direct drive as fast as possible
- Demonstrate efficiency of the vehicle by traveling at least 100 ft with the least amount of energy per pound of weight
- Design the regenerative braking to go as far as possible in the given 20 minutes

Vehicle Improvement Goals

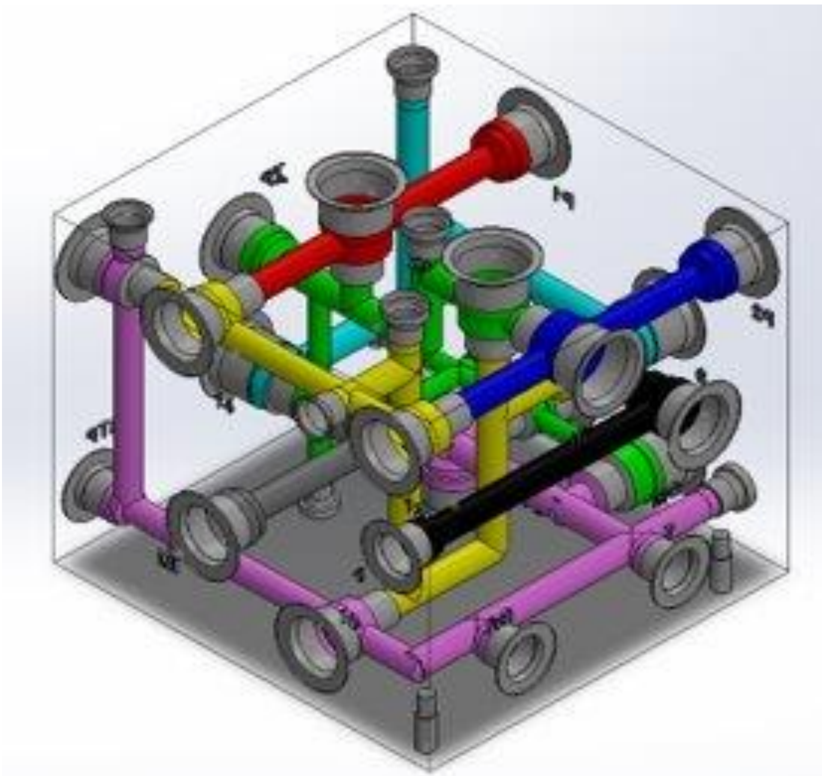
- Achieve different vehicle speeds with tandem pump
- Improve component placement
- Improve the regenerative braking circuit
- Implementing a pneumatic component
- Create more advanced controls including automatic valve activation

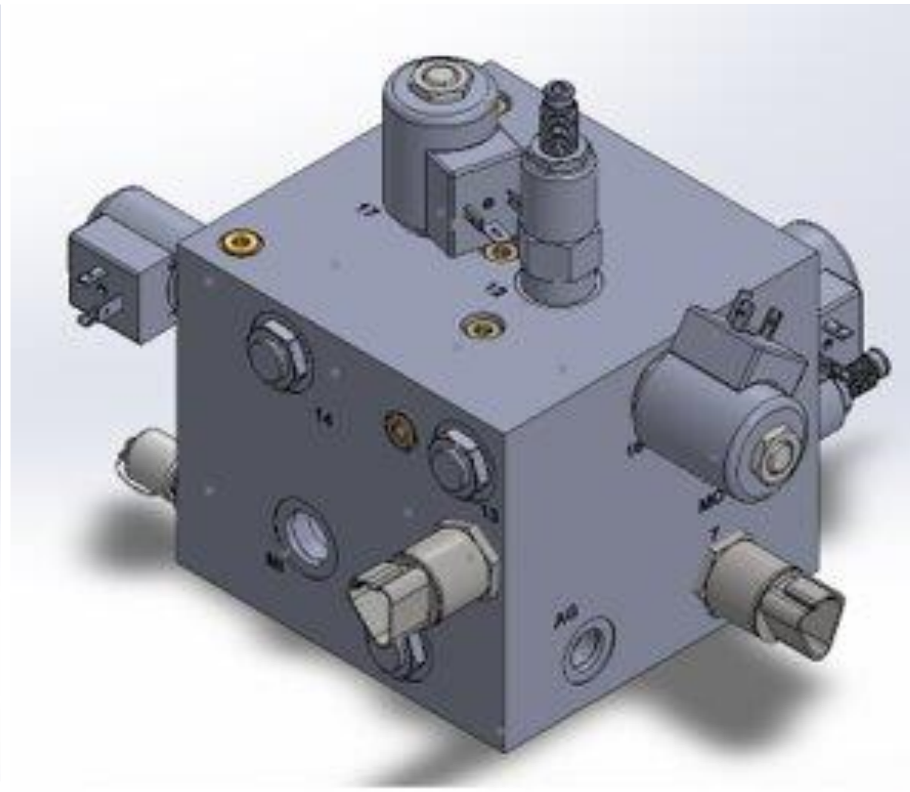
Design Recap

Fluid Circuit Design

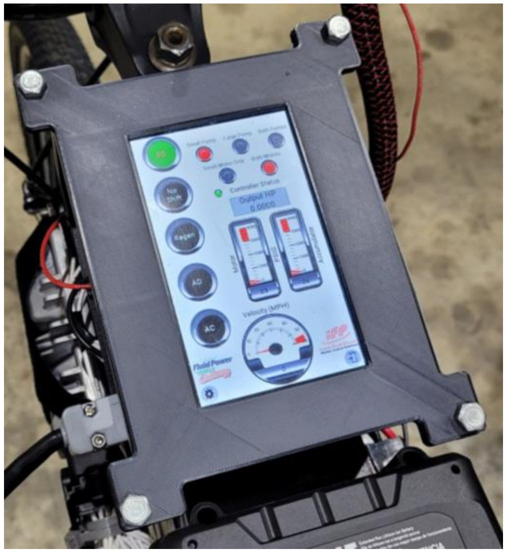


Custom Manifold



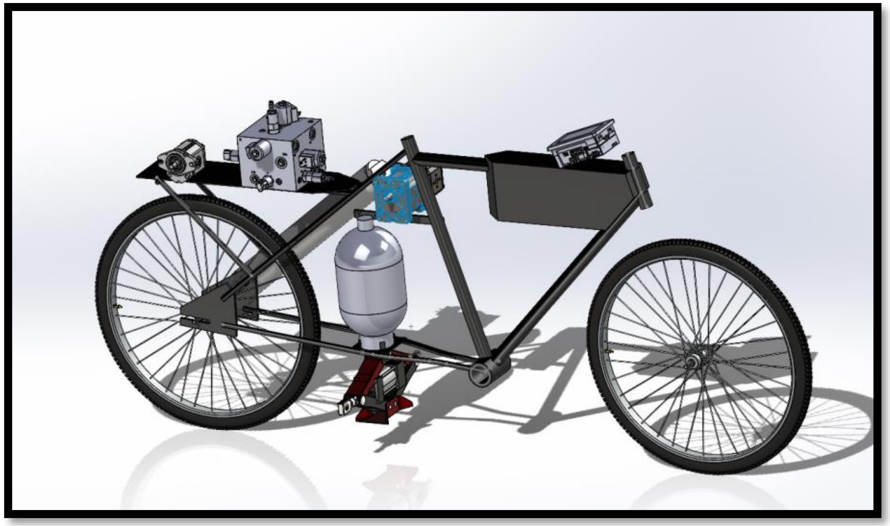


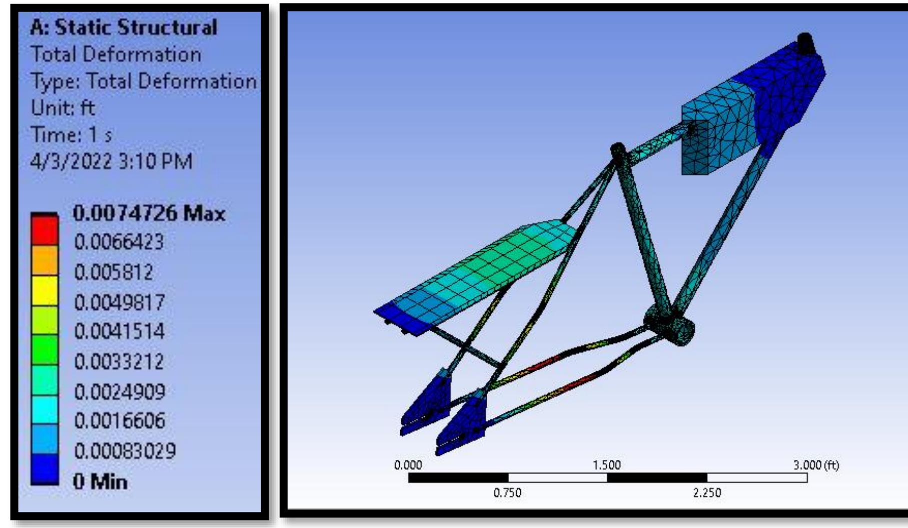
Controls Design



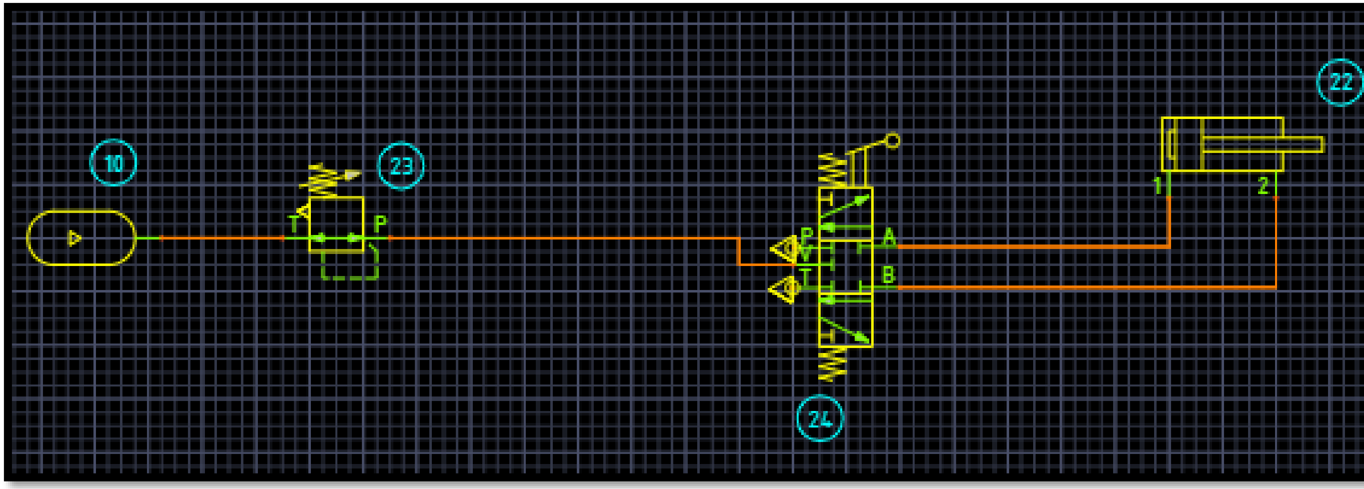
- Touch screen to control drive modes and display pressure, speed, and input/output horsepower
- Sensors provide input to controller
- Controller automatically switches pumps and motors for increased efficiency and safety
- 3D printed screen case and inductive sensor brackets

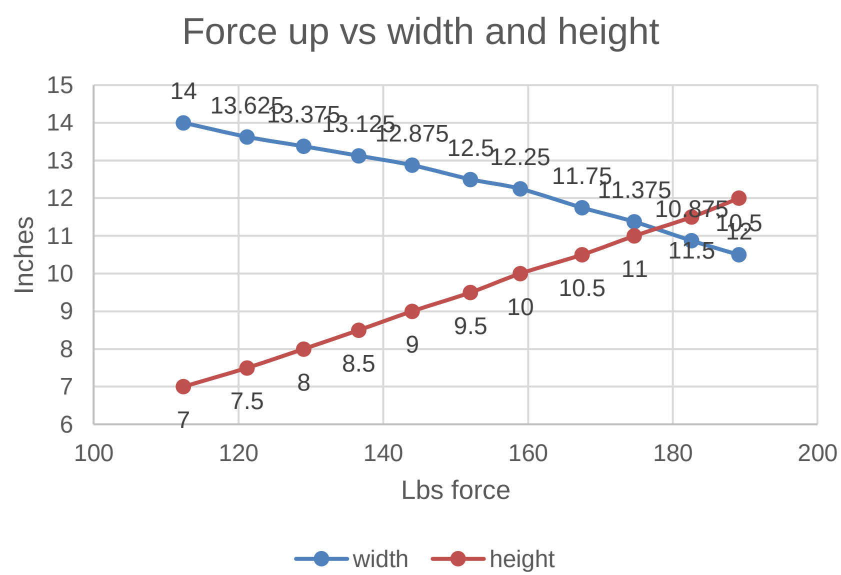
Frame Design





Pneumatics Design





Midway Summary

Midway Judges Feedback

- Mount pneumatic receiver close to cylinder
  - Original cylinder placement was closer to receiver but had to be moved due to space concerns
- Compare previous race results to current testing
  - Replicated races for performance comparisons to last year's vehicle.
- Set pumps and motors to switch based off rider power
  - Used pedal inductive sensor and pressure transducer at pumps to calculate rider HP
  - Testing showed rider HP to be too volatile as rider input is inconsistent
- Add a safety factor to the FEA
  - Added a factor of 10 to the FEA and determined it was safe

Results and Analysis

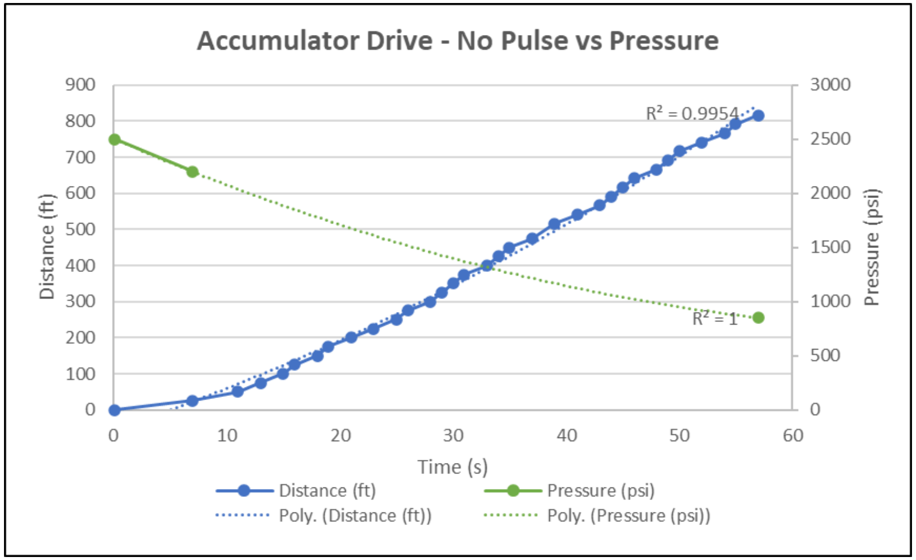
Direct Drive and Regen Results

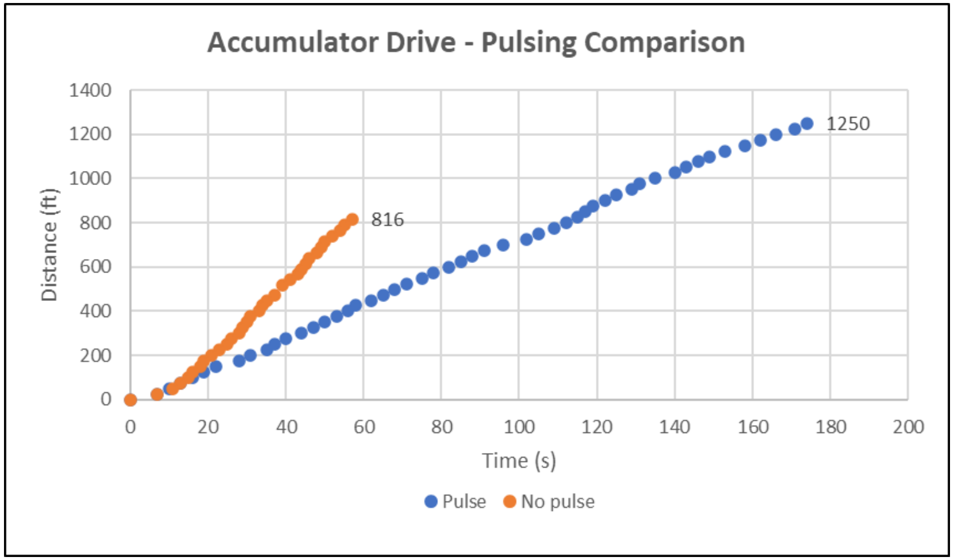
Direct Drive Data					
Rider	Top speed (mph)	Time to top speed (s)	Acceleration (fps^2)	500ft time (s)	Max HP
1	11.00	28.11	0.39	45.21	0.09
2	10.00	50.00	0.20	51.62	0.09
3	8.00	38.00	0.21	60.90	0.09
Average	9.67	38.70	0.27	52.58	0.09

Regen Data			
Rider	Speed (mph)	Pressure (psi)	Distance After Charge (ft)
1.00	11.00	941.00	27.00
2.00	10.00	934.00	9.00
3.00	8.00	930.00	3.00
Average	9.67	935.00	13.00

- Multiple pressure and flow combinations do aid rider in vehicle operation.
  - Easy to start pedaling, then greater resistance for increased consistency.
- Able to build adequate pressure from regen braking to start vehicle movement again.

Accumulator Drive Results

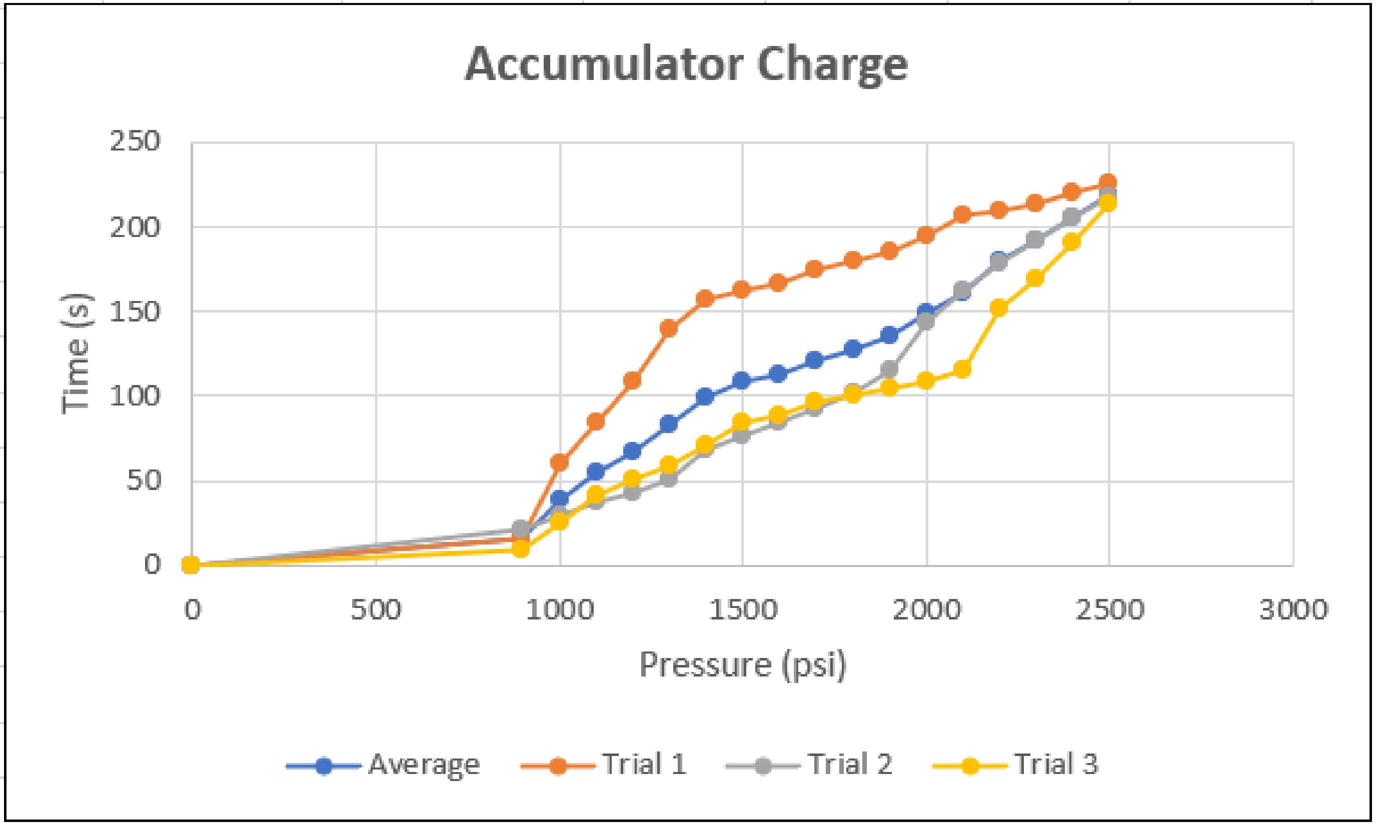




- Charge accumulator to max pressure, release pressure all at once. Re-do test but with "Pulse and Coast" method.
- Pulsing method allows for fluid conservation and maximum efficiency.

No pulsing efficiency: 7.87%, Pulsing efficiency: 12.06%

Accumulator Charge Results



- Automatic pump switching aids rider in charging.
  - Small pump makes accumulating pressure comfortable for rider.
- Pumps switch at 850psi and 1000psi.
- Average time to charge, 3:38 minutes.

Previous Year Comparisons

Previous Year UC Race Comparisons			
Race	2019	2021	Current
Sprint (s)	36.91	67.81	45.21
Efficiency (%)	1.7	14	12
Endurance (min)	-	10:09	n/a

- Current sprint results do not beat 2019 vehicle; however, racetrack and rules for 2019 are unknown.
- Current efficiency is less than 2021, however some metrics for 2021 were assumed.
- Endurance challenge has been changed since 2019.

Lessons Learned

Key Learnings from Testing

Learning: Hydraulic pumps cannot switch off input HP as planned. Too volatile due to rider input.

Solution: Pumps/motors switch off velocity instead.

Learning: Motor chain loosens when high force is applied due to frame design.

Solution: Added idler gear and support bracket to keep chain tight.

Learning: Accumulator pre-charge is vital to vehicle performance.

Solution: Copious amounts of testing needed to find the optimal value.

Learning: Direct drive top speed is only 11 mph. Resistance on pedals makes it difficult to pedal fast and consistent with both pumps engaged.

Solution: Decrease gear ratio to pump or add straps to pedals to create more force.

Thank you, Questions?