NFPA Fluid Power VEHICLE Challenge

NFPA Education and Technology Foundation

Final Presentation

Kennesaw State University

April 12th, 2024

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Team Introductions

Stefan Glende
Project Manager and Hydraulic Design

Avery Garrett
Mechanical Design and Simulation

Matthew Fierro-McCarthy
Pneumatics and Vehicle Testing

Austin Arnold
Calculations and Testing

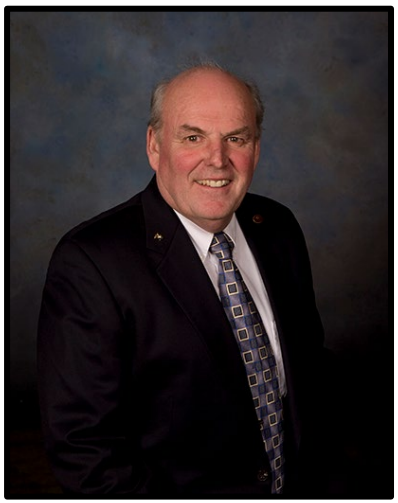
Brandon Tomaskovich
Electronics and Mechanical Design

David Amaya
Mechanical Design and Testing

Team Introductions

Laura Ruhala Ph.D.
Asst. Dept. Chair
Mechanical Engineering
Kennesaw State University

Richard Ruhala Ph.D.
Professor
Mechanical Engineering
Kennesaw State University



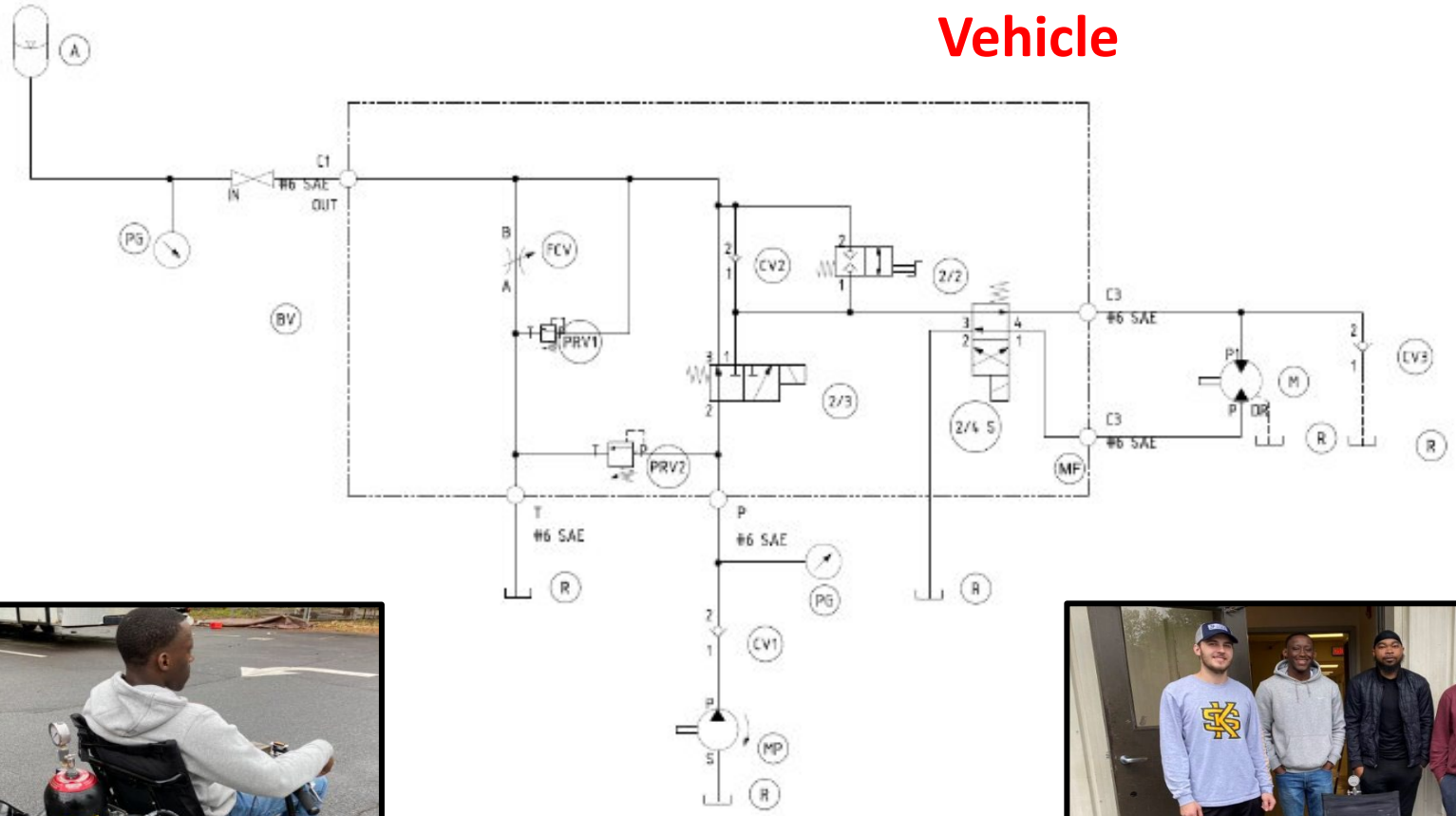
Ernie Parker
International Fluid Power Society

Cory Fisher M.S.
Sun Hydraulics

2022-2023 Overview

NFPA Fluid Power Vehicle Challenge

Last Year's Vehicle



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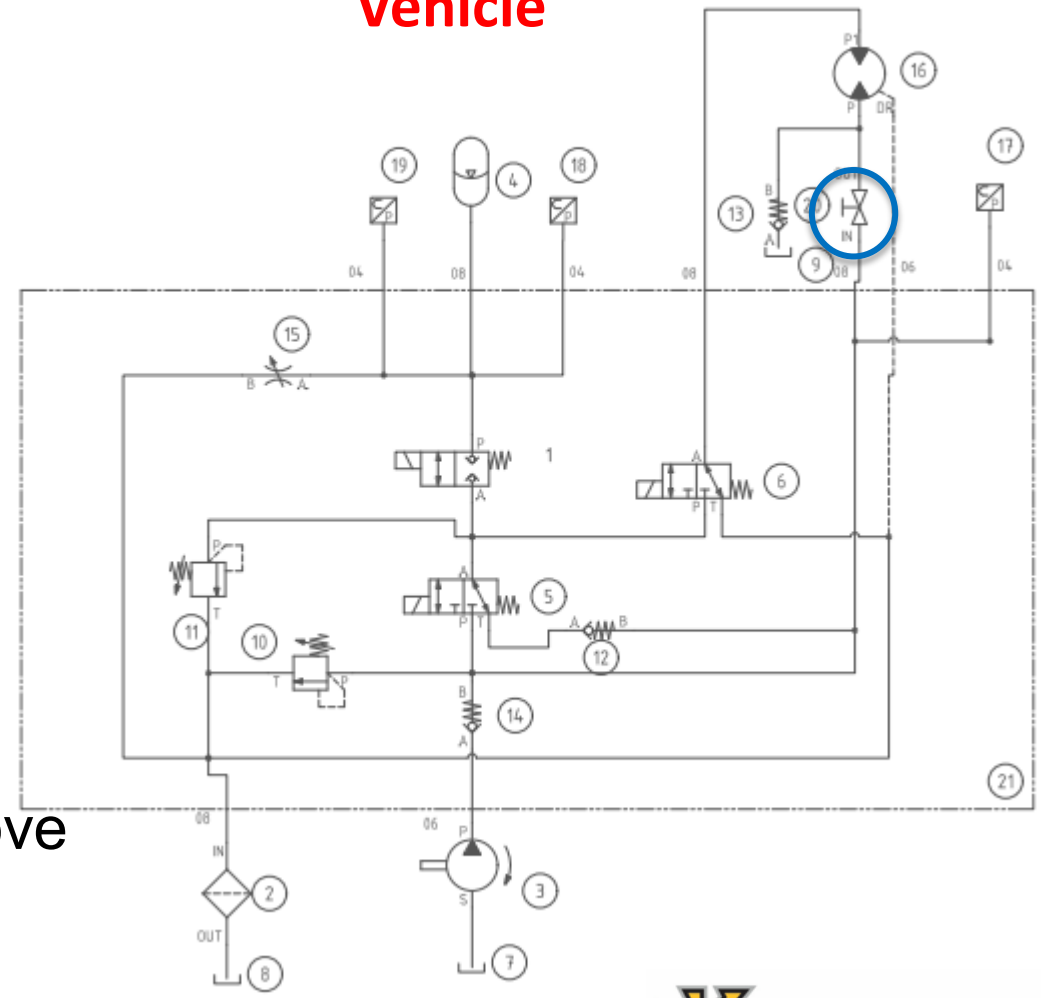
Final Hydraulic Circuit

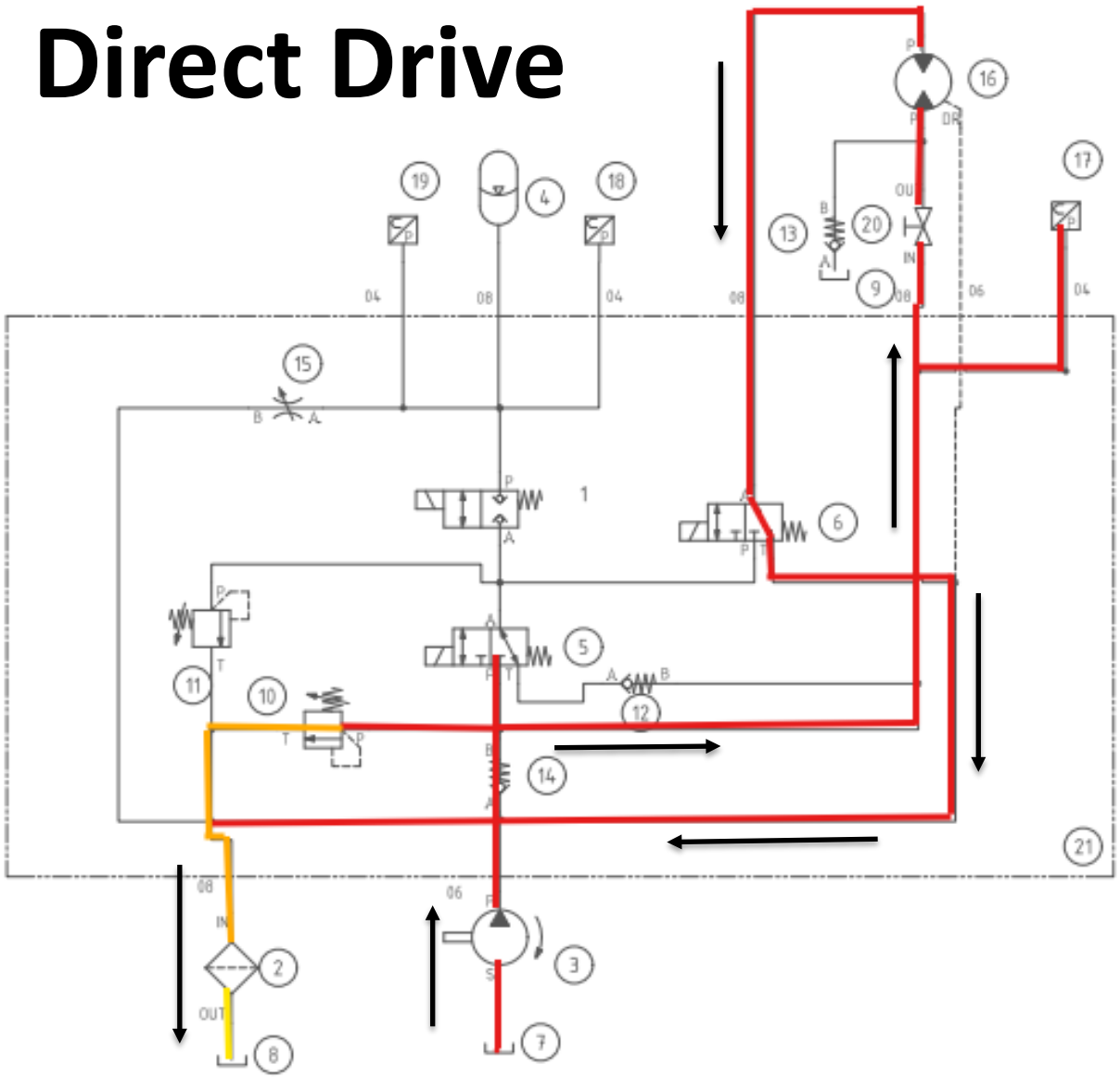
- Fail safe to direct drive
- Added filter to eliminate contaminants
- Changed ball valve to eliminate leakage
- 2-way valve before accumulator benefits
- Only transducers to improve electronics

Current Vehicle



2024 Hydraulic Circuit

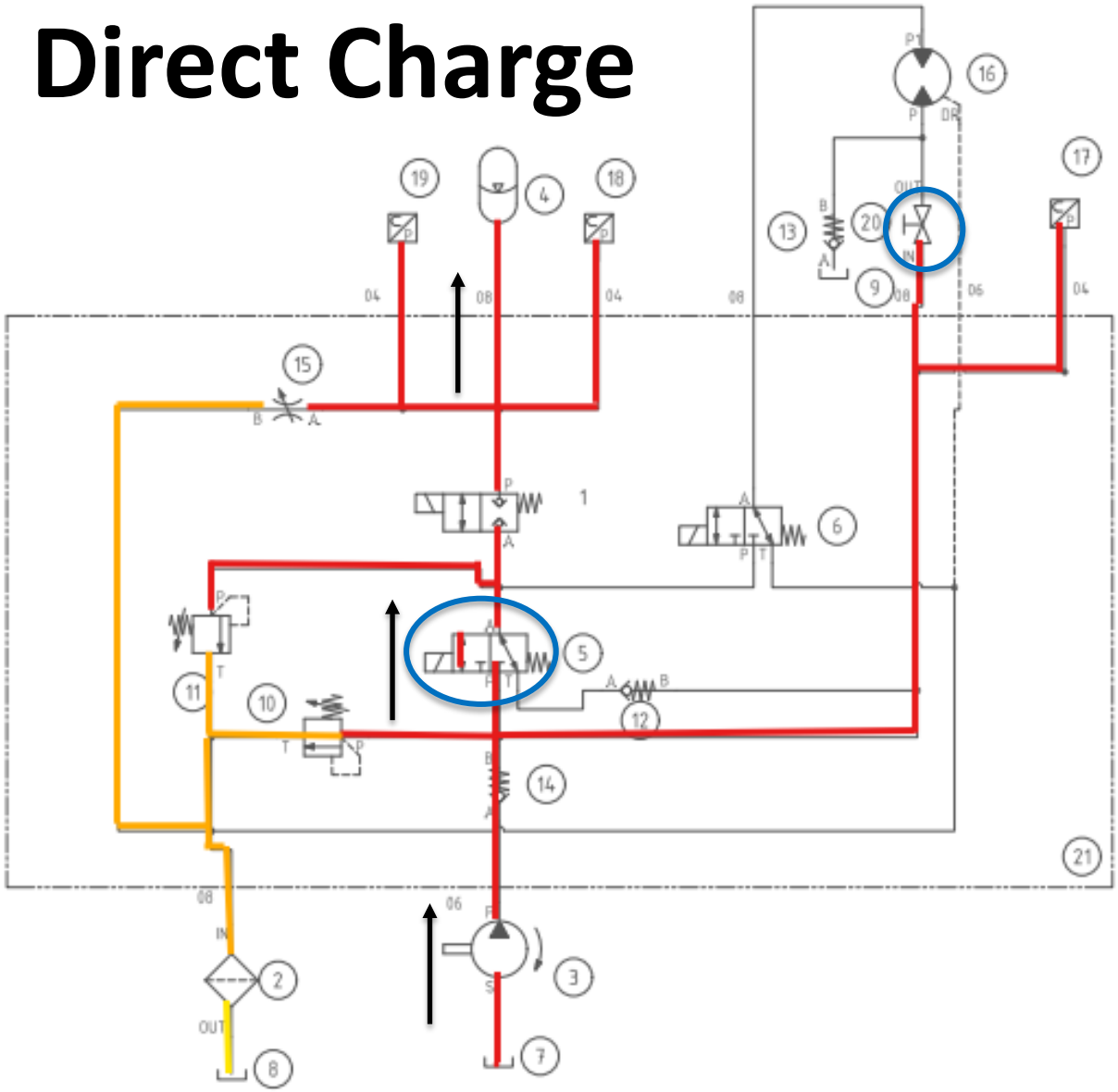
Direct Drive



Color	Scheme
Red	Working Fluid
Orange	Pressure Reduction
Yellow	Flow slowing down

2024 Hydraulic Circuit: Direct Drive Mode

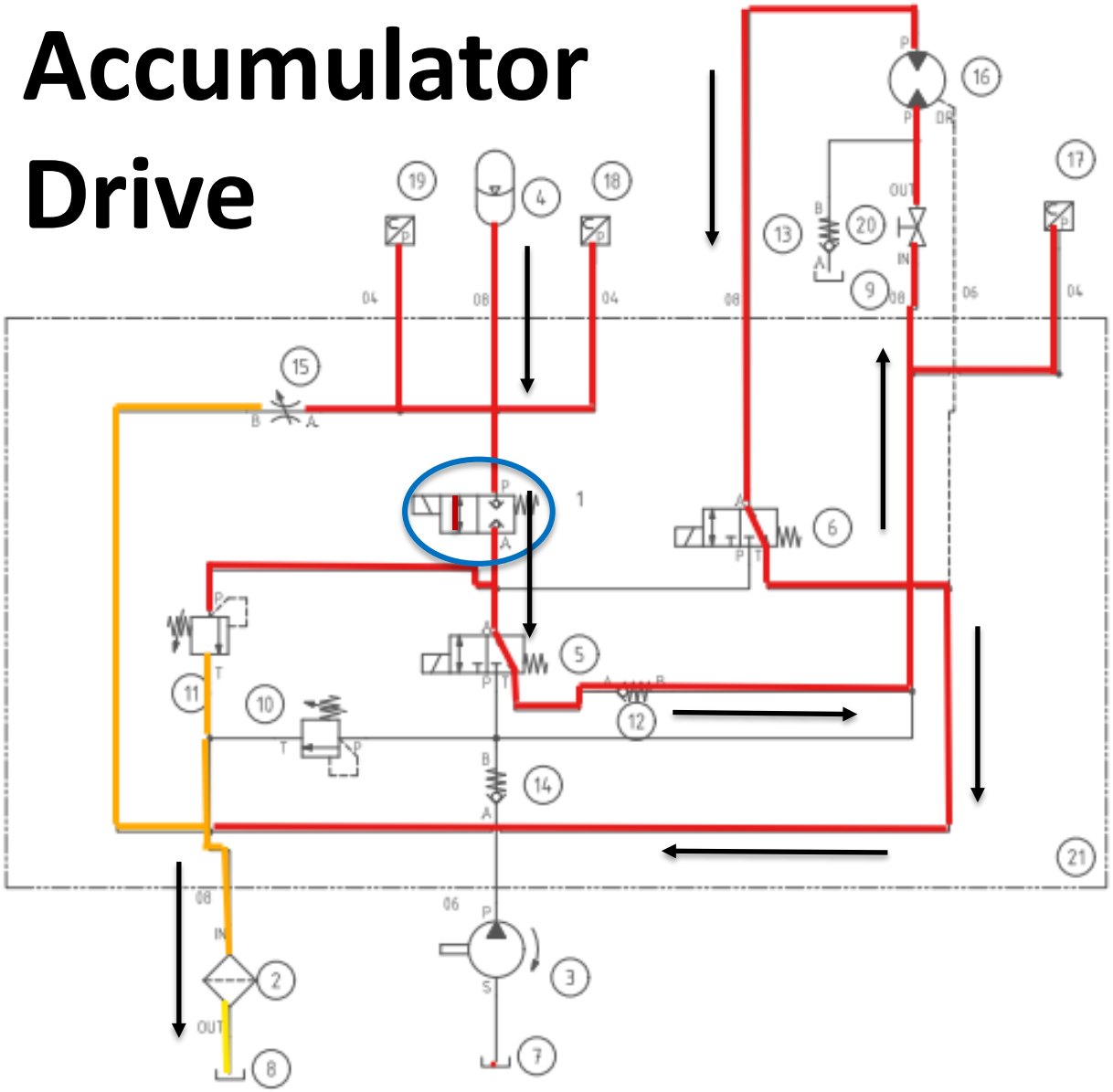
Direct Charge



Color	Scheme
Red	Working Fluid
Orange	Pressure Reduction
Yellow	Flow slowing down

2024 Hydraulic Circuit: Direct Charge Mode

Accumulator Drive



Color	Scheme
Red	Working Fluid
Orange	Pressure Reduction
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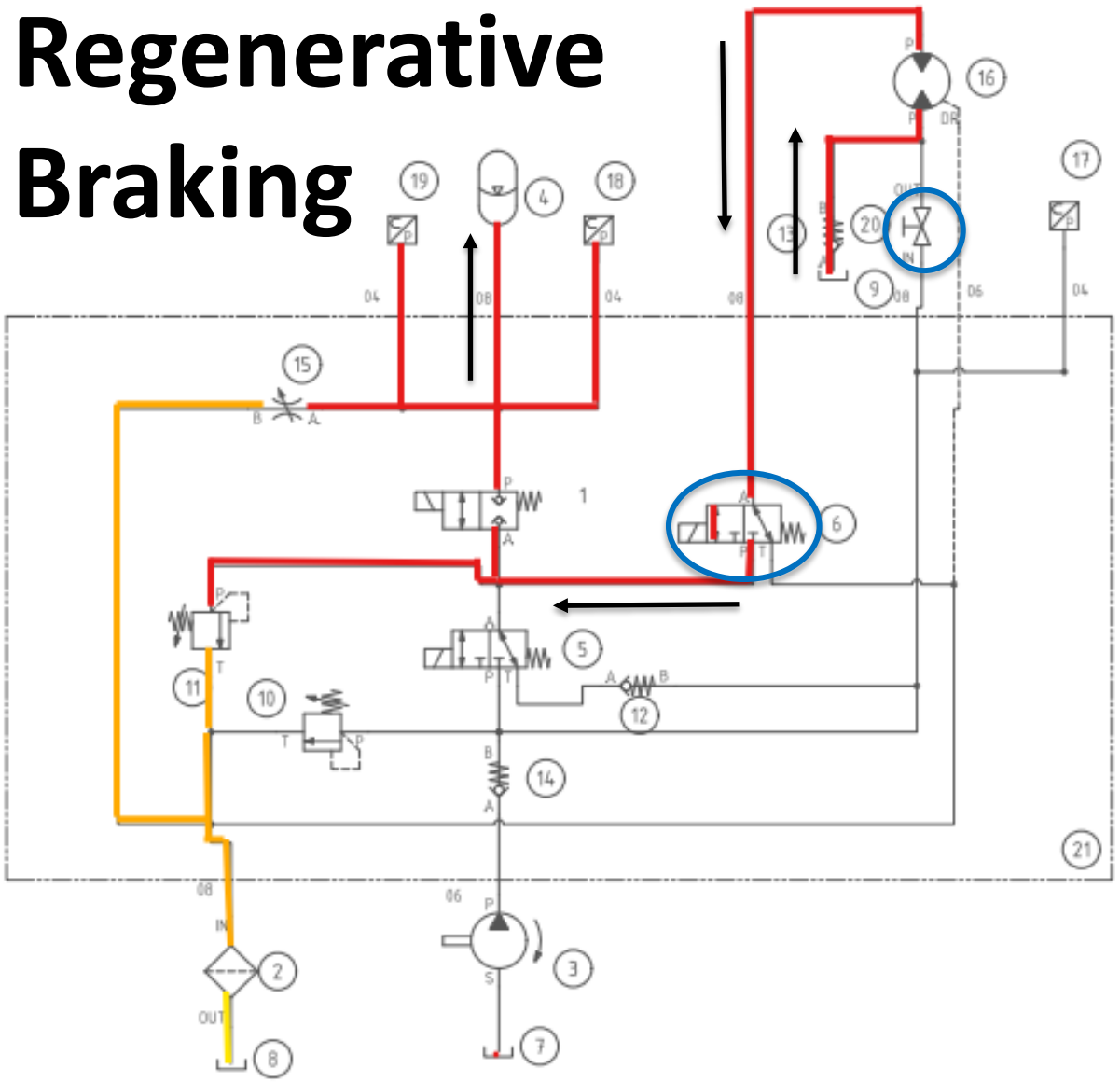
2024 Hydraulic Circuit: Accumulator Drive Mode

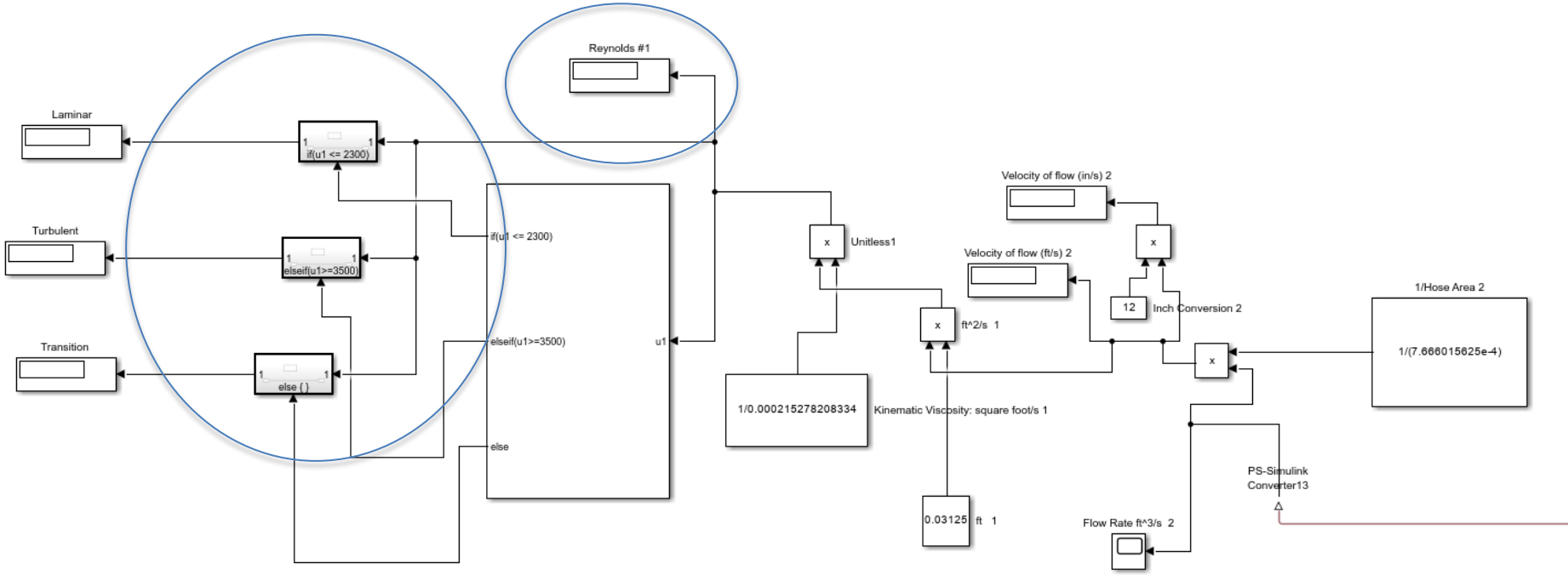
Regenerative Braking



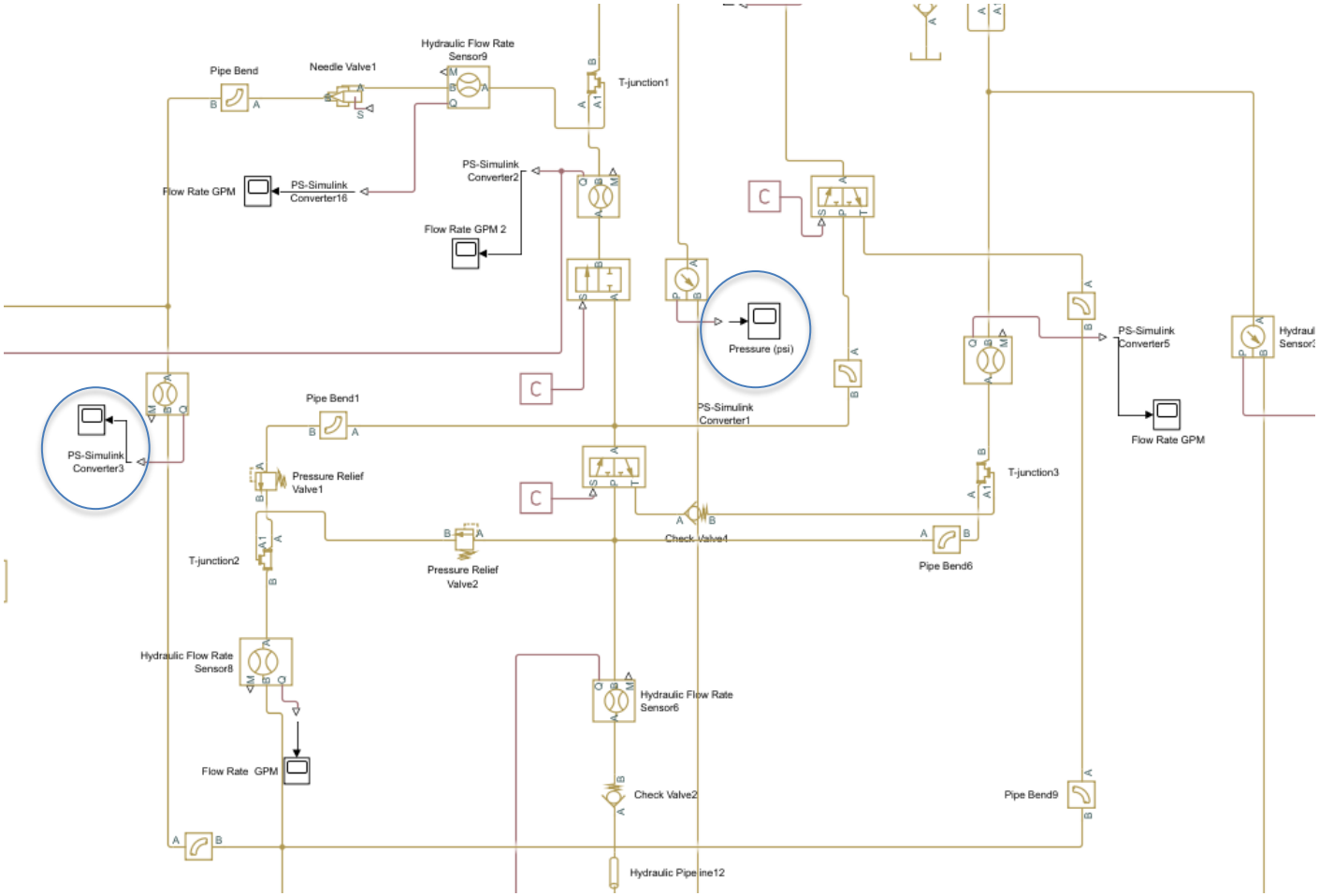
Color	Scheme
Red	Working Fluid
Orange	Pressure Reduction
Yellow	Flow slowing down

2024 Hydraulic Circuit: Regenerative Braking Mode

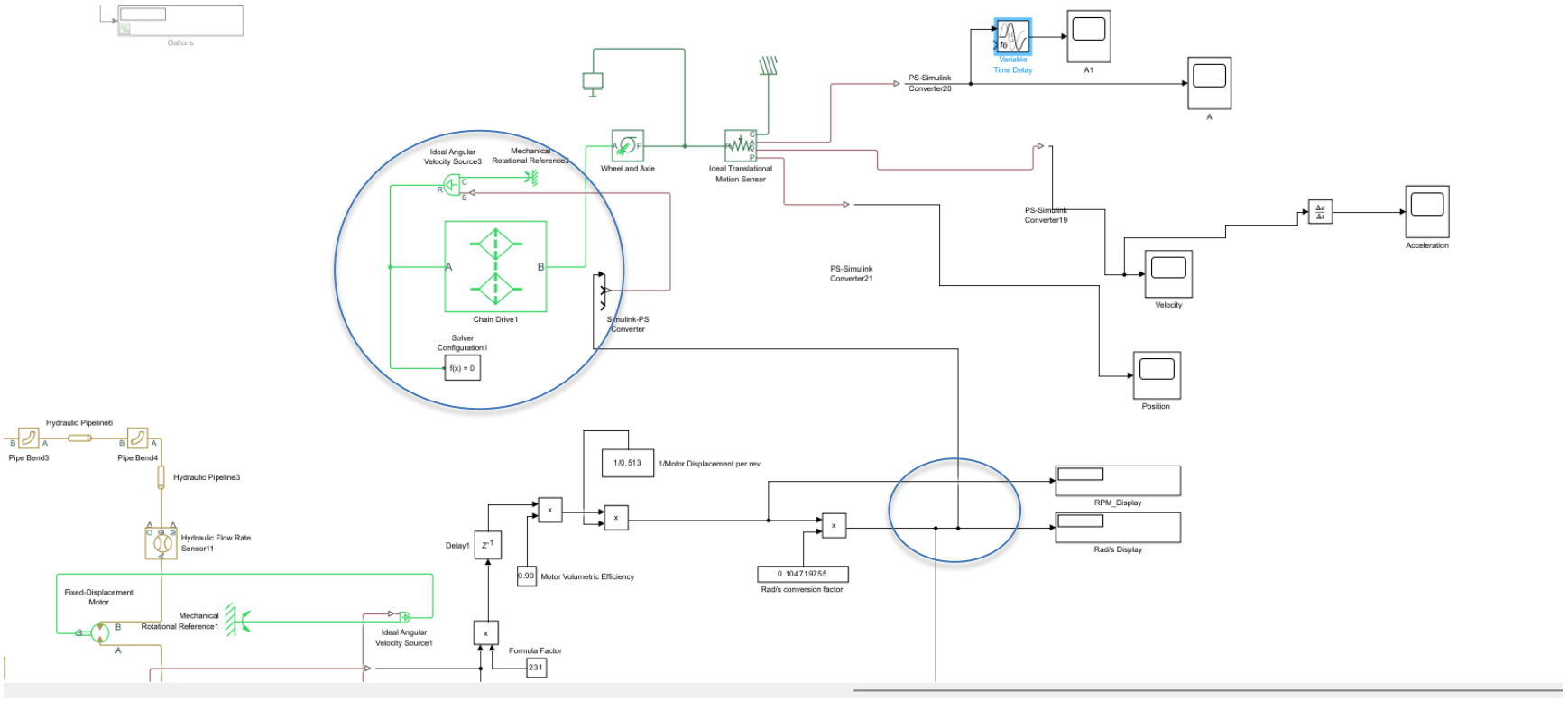
MATLAB Simulink Model



MATLAB Simulink Model

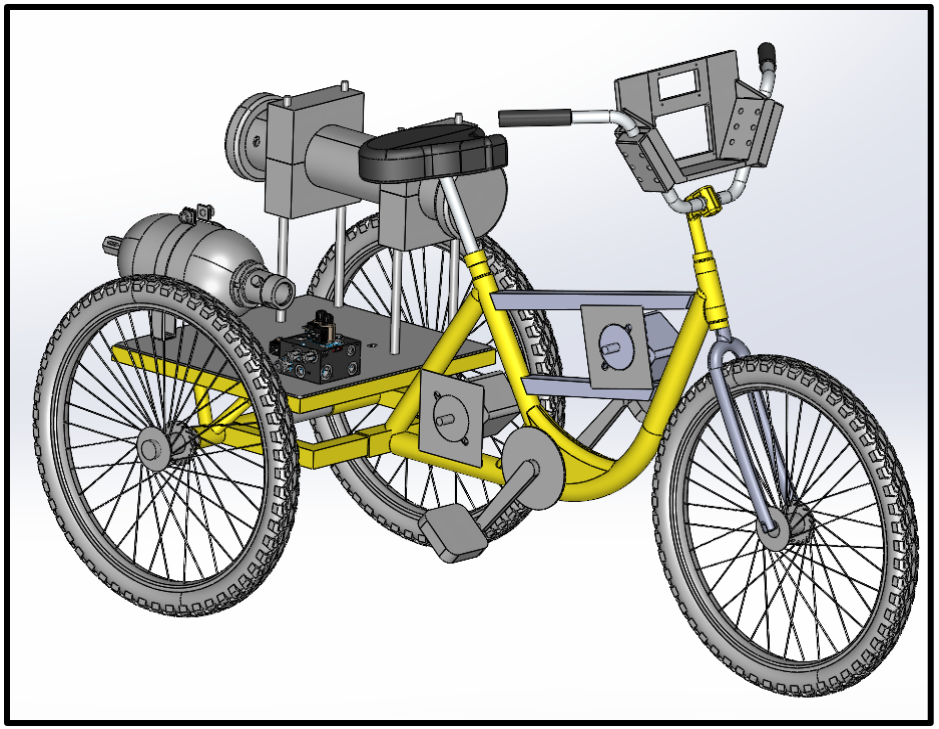


MATLAB Simulink Model

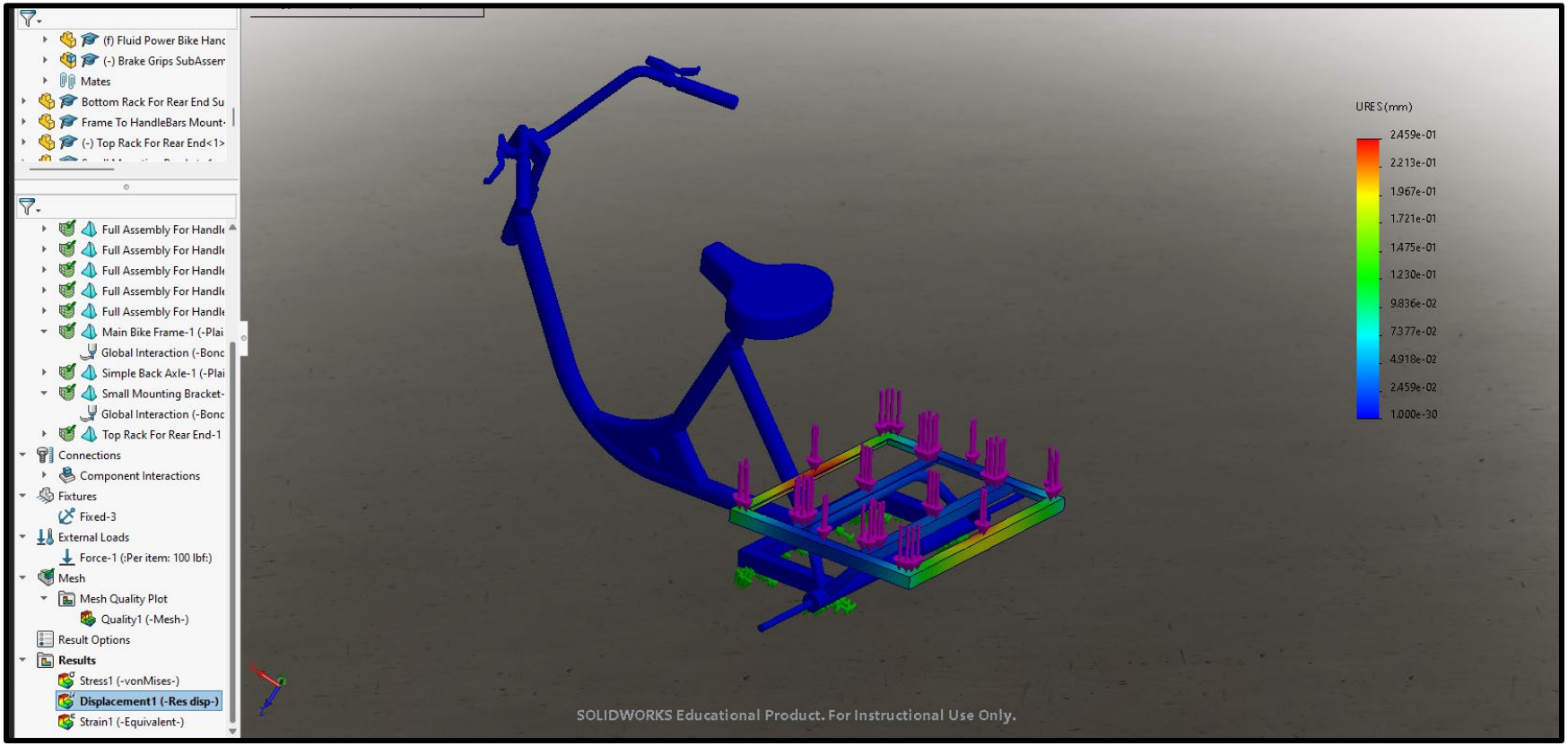


CAD

- Model of frame based on exact dimensions
- Full assembly used to estimate clearances and fitments
- Computer aided engineering (CAE) simulations ran on mounts added to vehicle

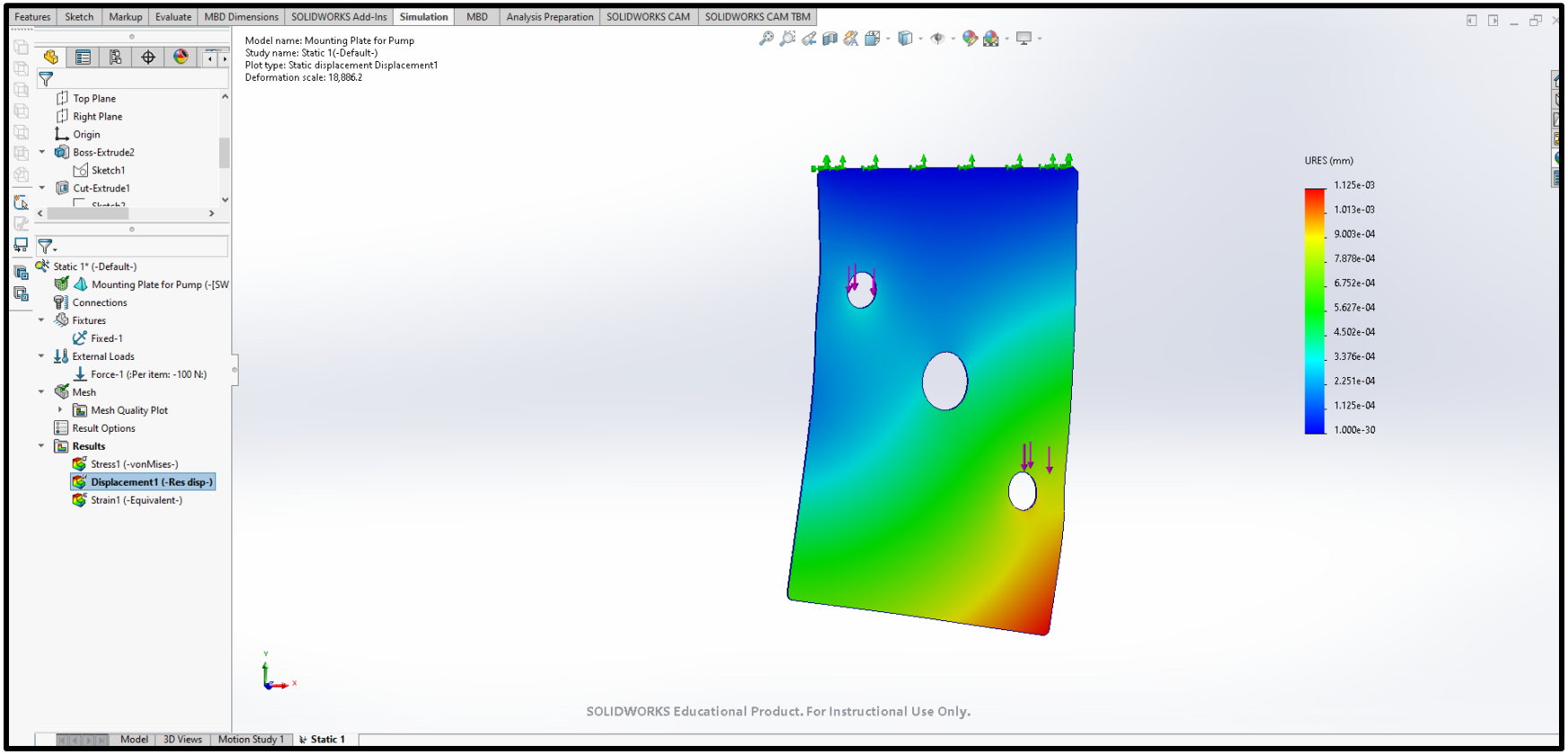


CAE – Frame



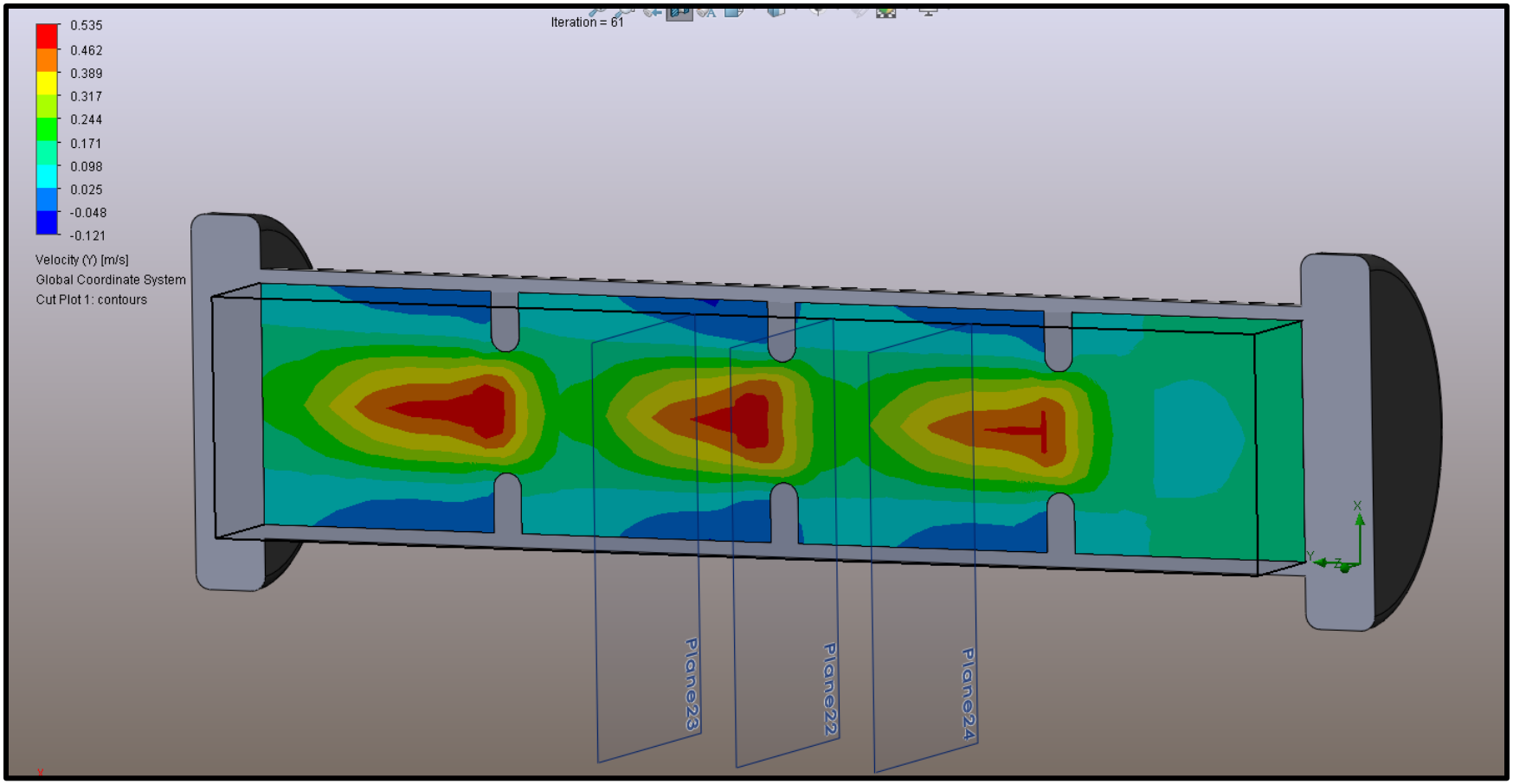
Plain Carbon Steel

CAE – Pump Mount



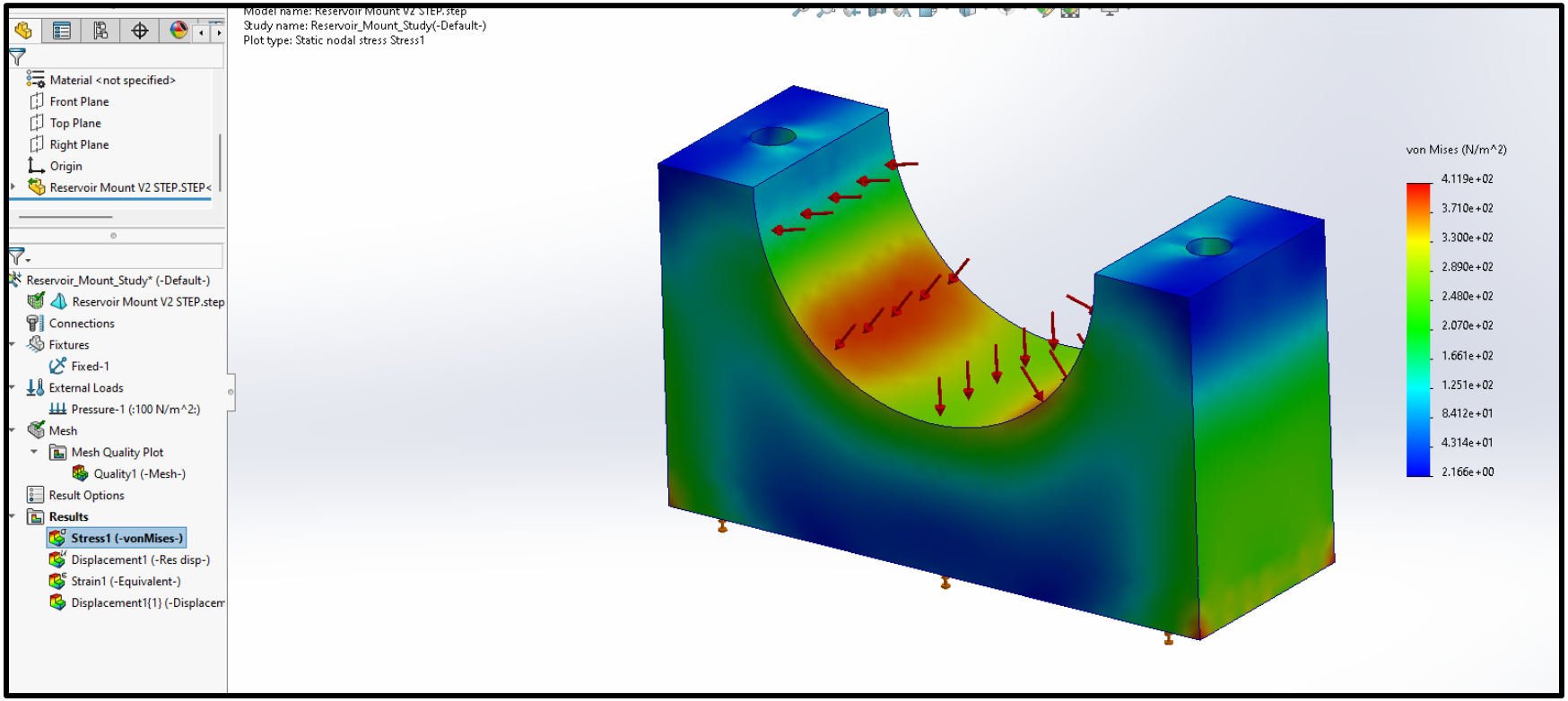
Pump Mounting Plate with 100 N force on bolt holes.

CAE – Reservoir Internal Flow



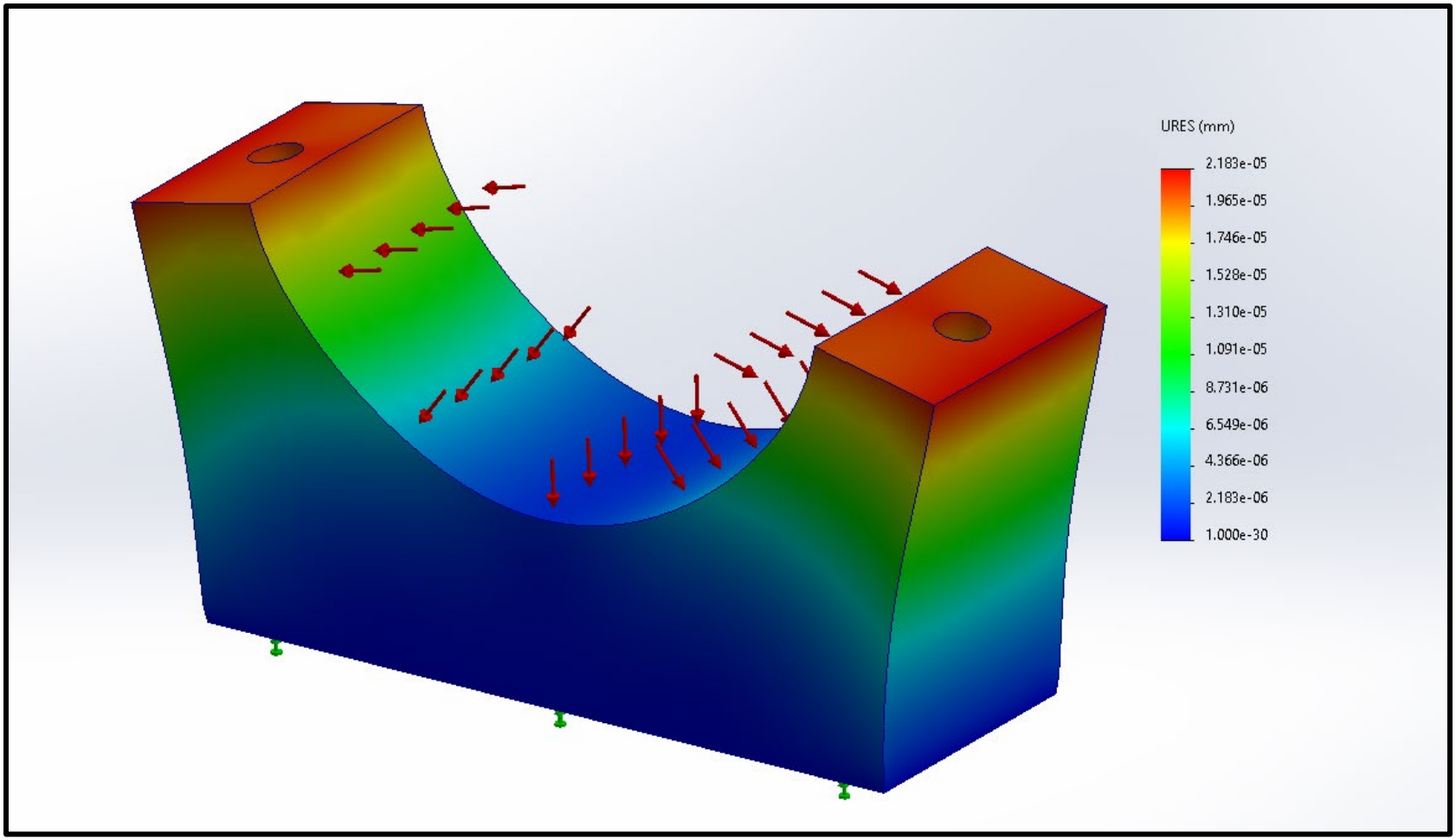
SolidWorks Simulation

CAE – Reservoir Mounting

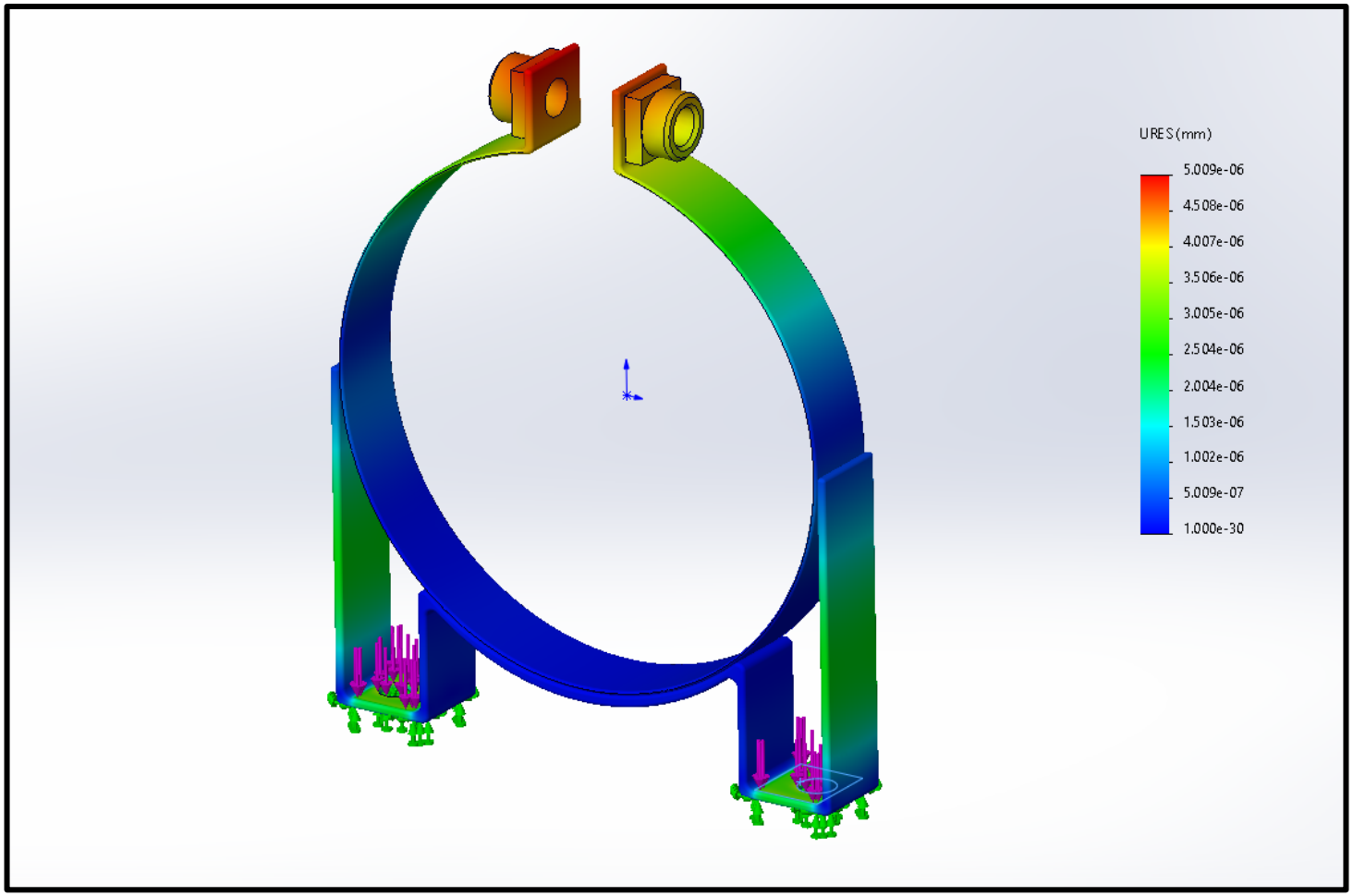


ABS

CAE – Reservoir Mounting

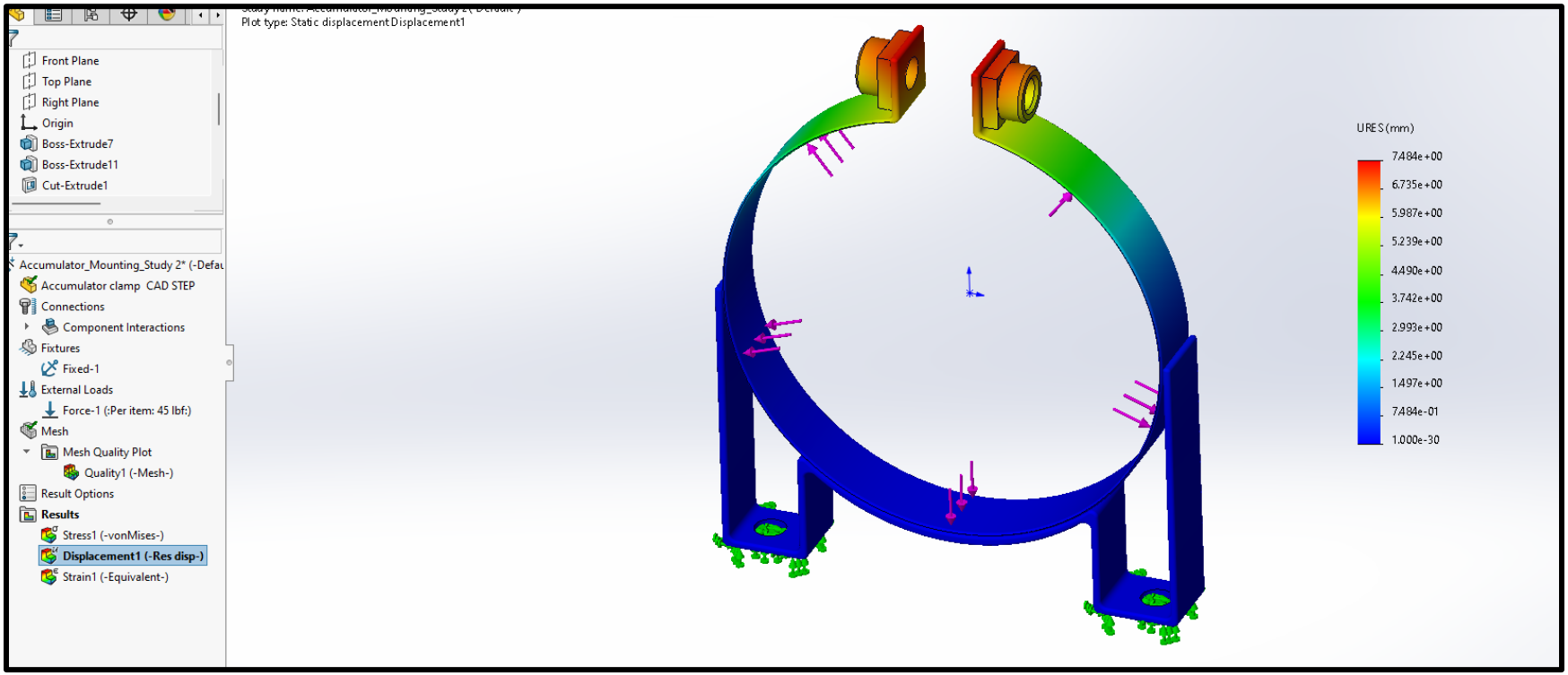


CAE – Accumulator Mounting



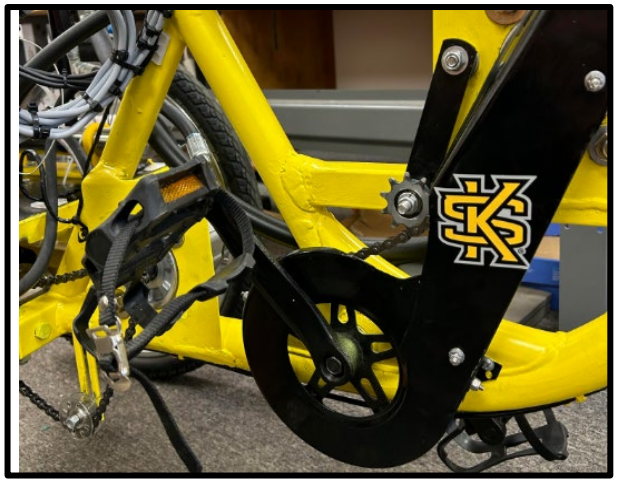
Galvanized Steel

CAE – Accumulator Mounting



Vehicle Construction

- Frame Modifications
  - Steel back plate
  - Steel bars and plates for motor and pump mounting
  - Front basket for battery housing
  - Elevated reservoir housing

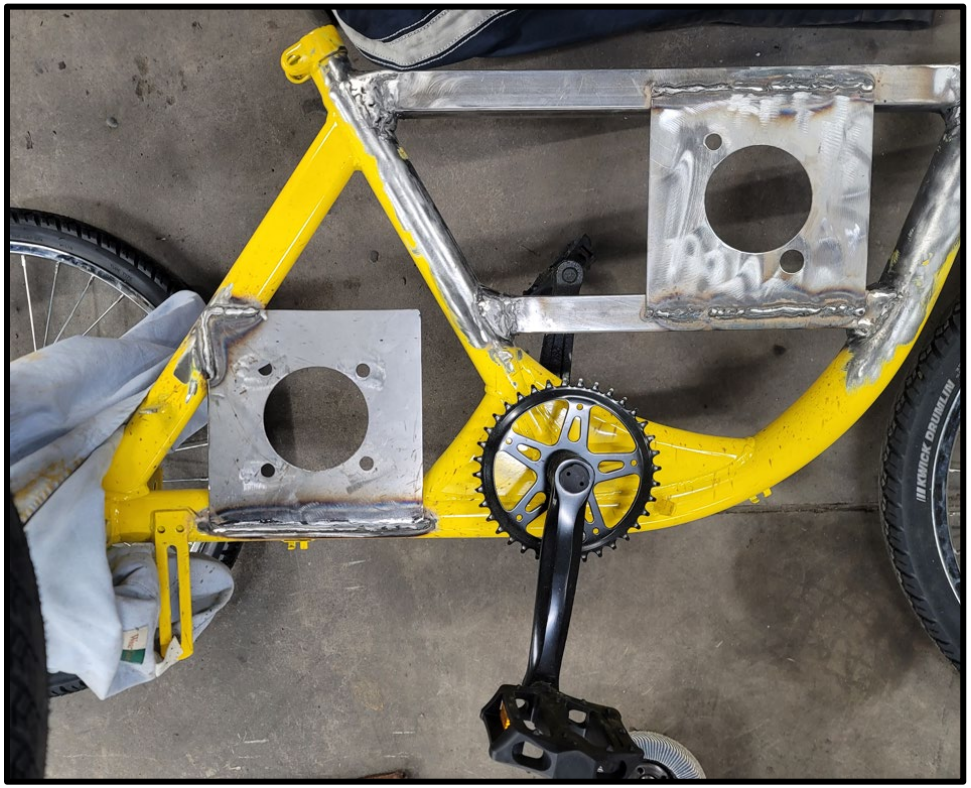


Completed Chainguards

Initial Frame

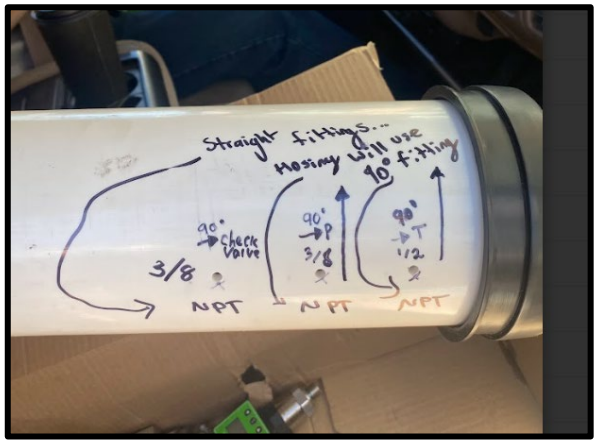
Final Frame (Minus Chainguards)

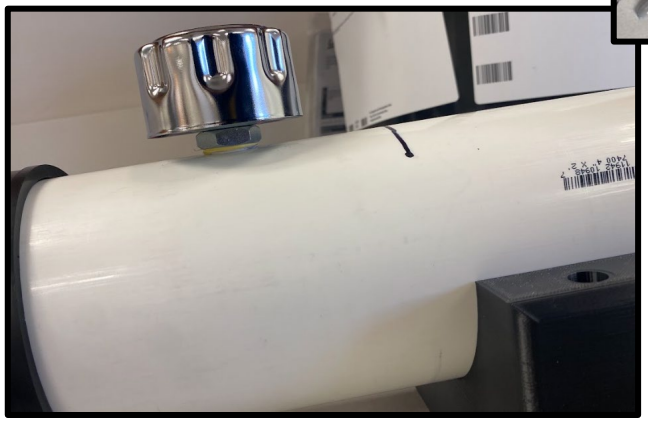
Vehicle Construction



Vehicle Construction

- Reservoir
  - Custom made using PVC pipe
  - Installed 3d printed baffles to reduce sloshing
  - 1 gallon capacity of fluid
  - Lightweight and easy install





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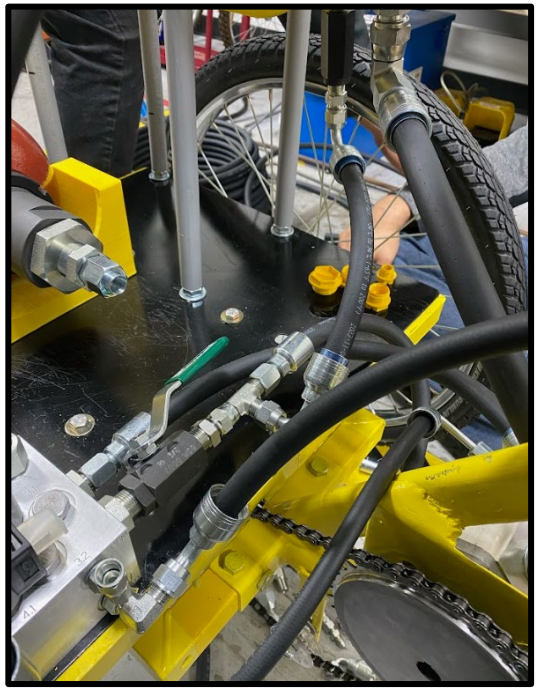
Vehicle Construction

- Attaching equipment
  - Manifold, Reservoir, and Accumulator to rear plate.
  - Motor and Pump attached to custom welded plates and spaced correctly for chain alignment.
  - Electrical and Pneumatic Equipment installed.

Hydraulic and Pneumatic Components on Back Plate

Vehicle Construction



Vehicle Construction

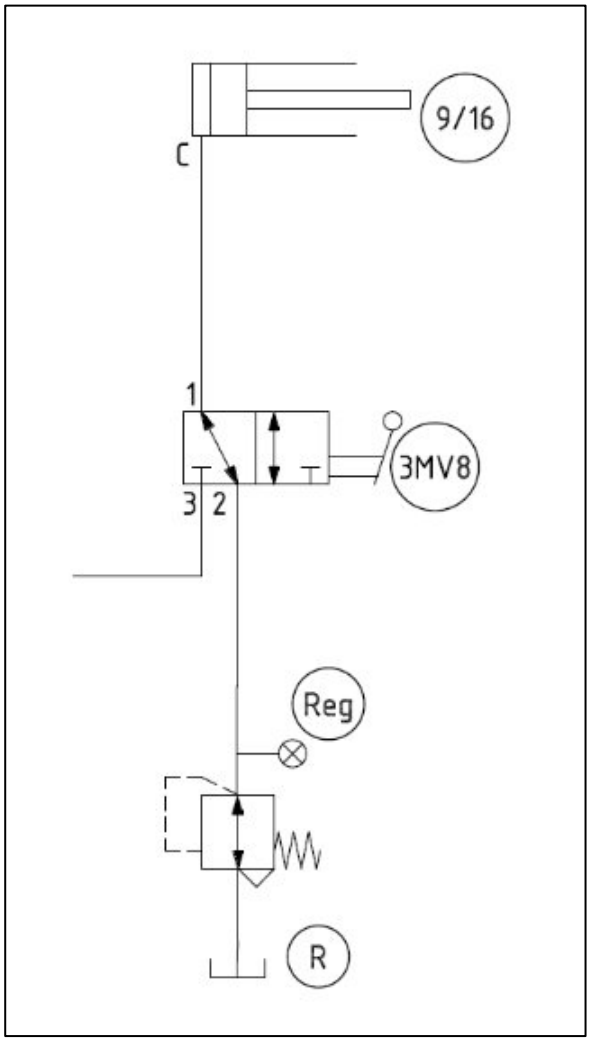
- Hosing Details
  - Hosing was provided by the Hydraulic Supply Co.
  - Provided us with the necessary hose lengths and fittings
  - The team made necessary adjustments when we tightened the hosing

Pneumatic Design

Last Year's Vehicle

- Last year's 2023 pneumatic design
- Used pneumatics for cup and phone holder

2023 Pneumatics on Vehicle

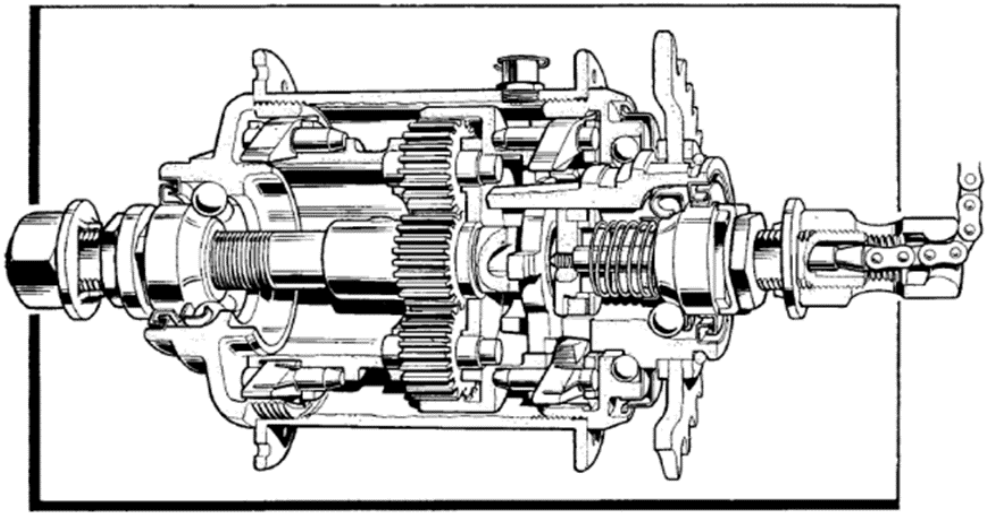


2023 Pneumatic Schematic

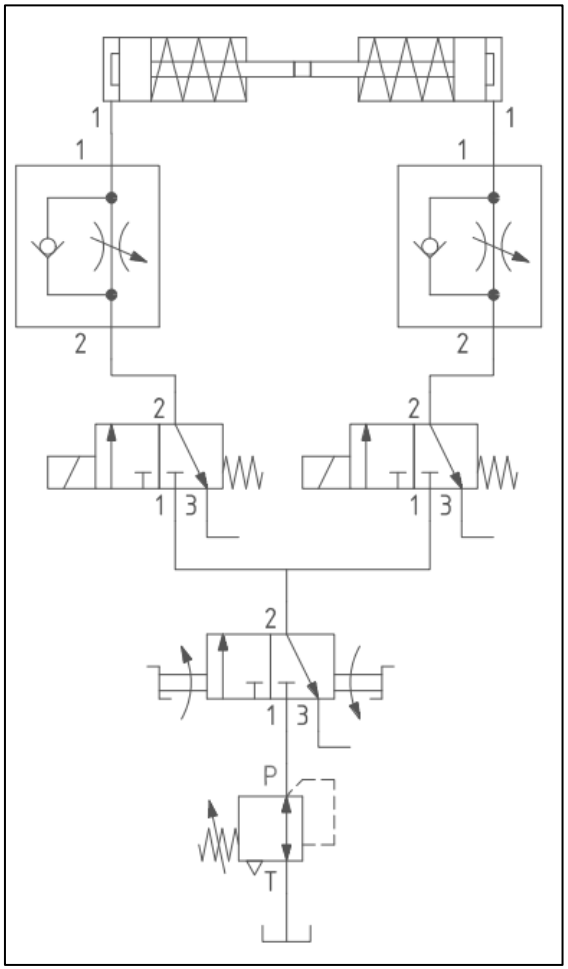
Pneumatic Design

Current Vehicle

- This year's 2024 pneumatic design
- Pneumatics used for gear shifting on vehicle
- Changed method of manipulating gears (Using internal gear hub instead of typical sprocket set)



Internal Gear Hub Schematic



2024 Pneumatic Schematic

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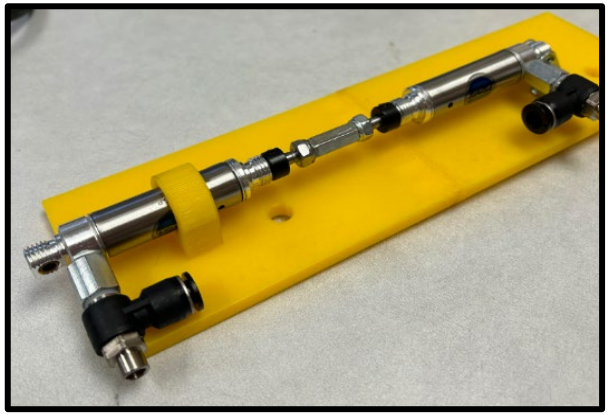
Pneumatic Design

Pneumatic Components



Cylinder Assembly and Mount

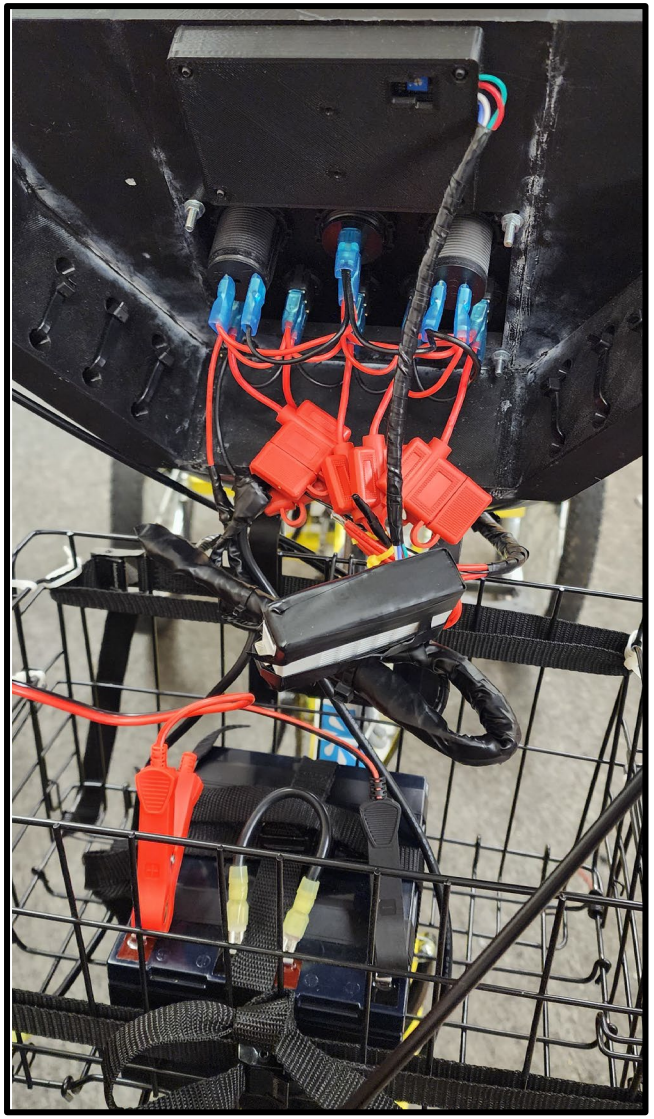
Cylinder Assembly Installed

Electrical System

- User-controlled drive modes using switch panels
- Heads-up LCD displays pressure transducer readings
- 5-gang switch panel
  - Customizable & accessible
  - 3 solenoid valves
  - 2 pneumatic actuators

Electrical System

- 24V source created with two 12V deep cycle batteries in series
  - Industry standard sensor voltage
  - Price
  - Weight
- System defaults to direct drive in the event of a failure
  - De-energized solenoid valves
  - 2023 lesson



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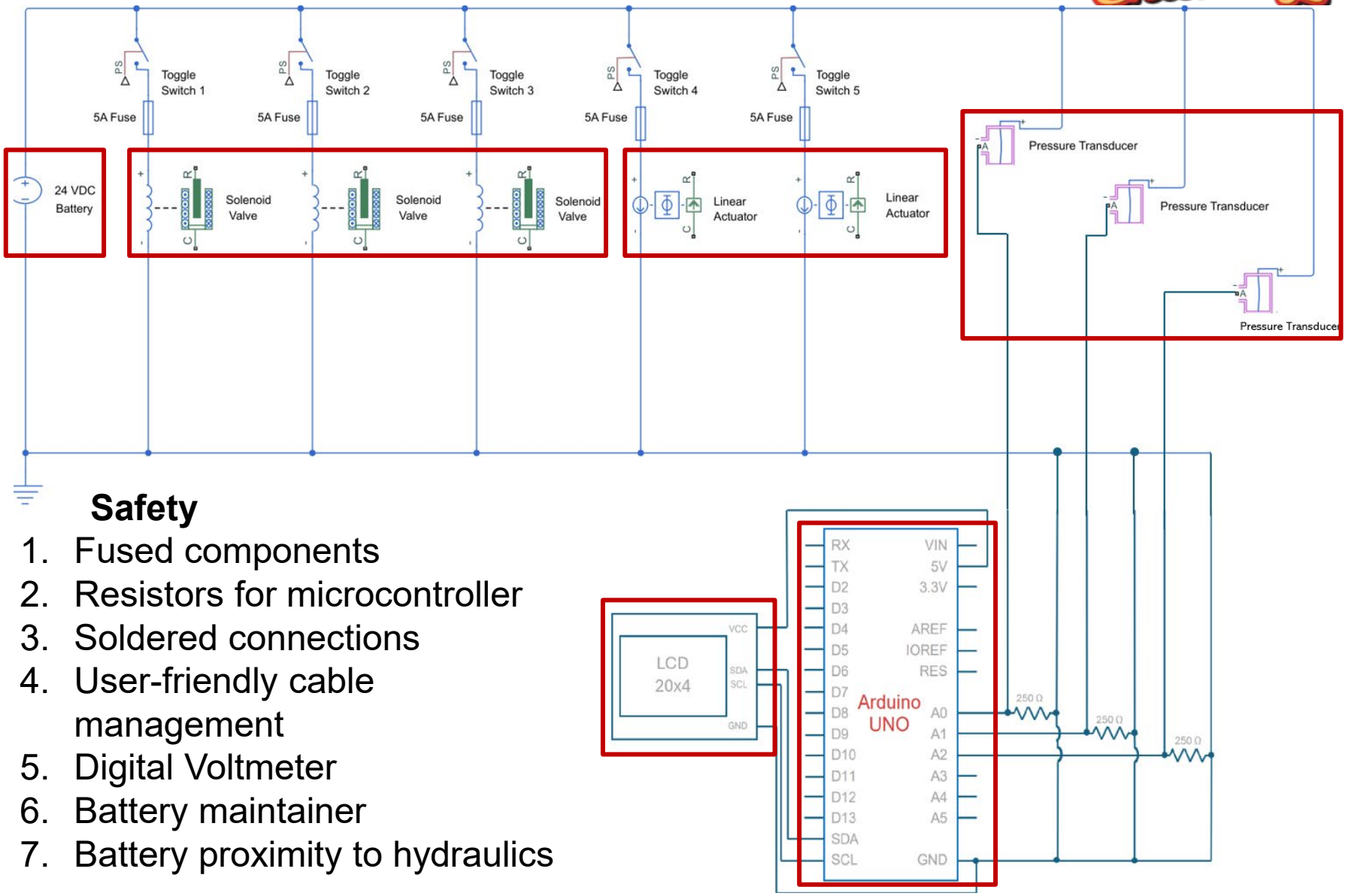
NFPA Fluid Power VEHICLE Challenge



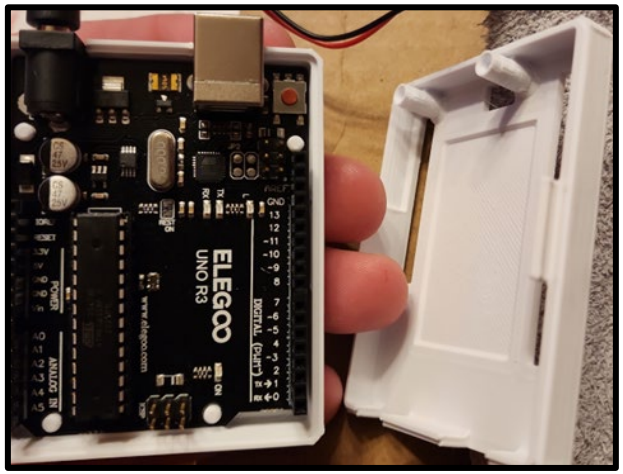
Safety

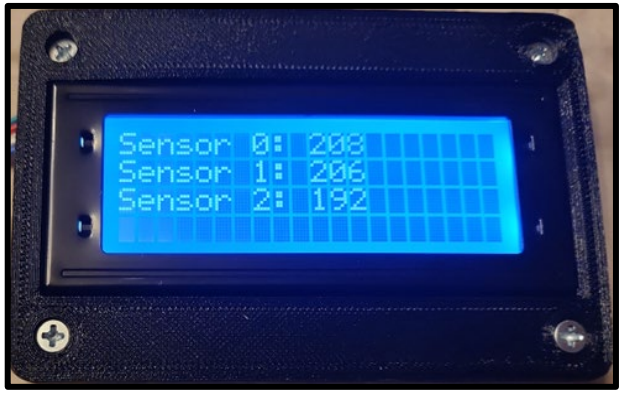
1. Fused components
2. Resistors for microcontroller
3. Soldered connections
4. User-friendly cable management
5. Digital Voltmeter
6. Battery maintainer
7. Battery proximity to hydraulics

Electrical System

- Arduino UNO R3 Micro-controller with LCD display
  - Lightweight
  - Adjustable Arduino IDE code
  - Efficiency calculation optimized
  - Controller & LCD Weight [0.27 lbs.]

$$Efficiency = \frac{Energy\ Out}{Input\ Energy} = \frac{Weight\ x\ cf\ x\ distance}{\frac{PSI_{avg}\ x\ Volume_{usable}}{12}}$$





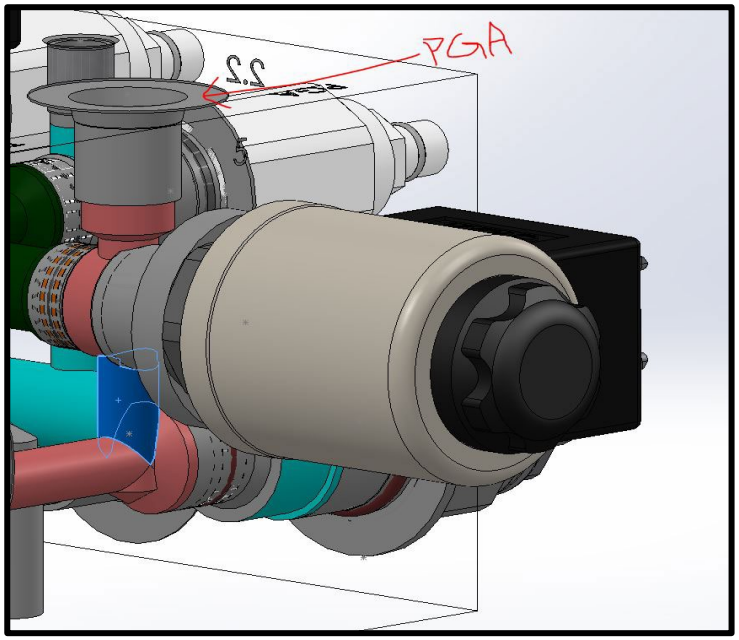
- HMI considered
  - Heavier weight
  - Excessive power consumption

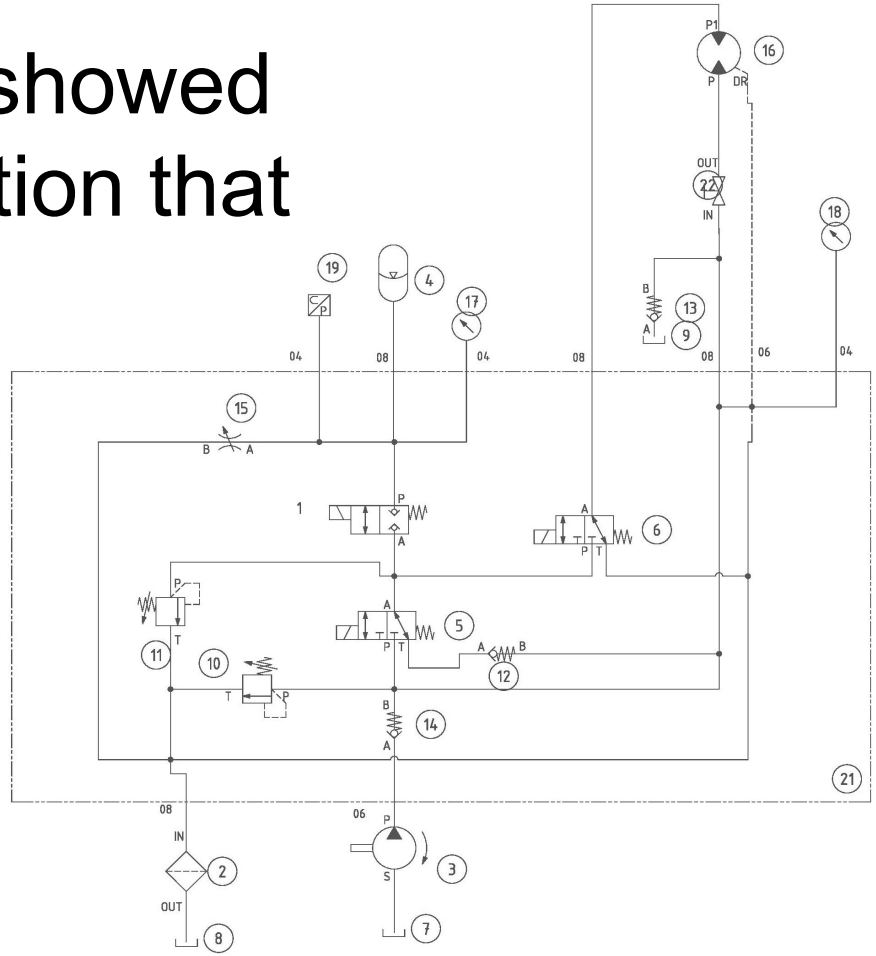
Vehicle Testing

- Continuous testing for 21 days
- Changed gearing ratio for greater focus on torque instead of speed
- Discovered the manifold was not machined correctly
- Conclusion: variety of factors prevented initial functionality
  - PRVS, gear ratio, etc.

Vehicle Testing

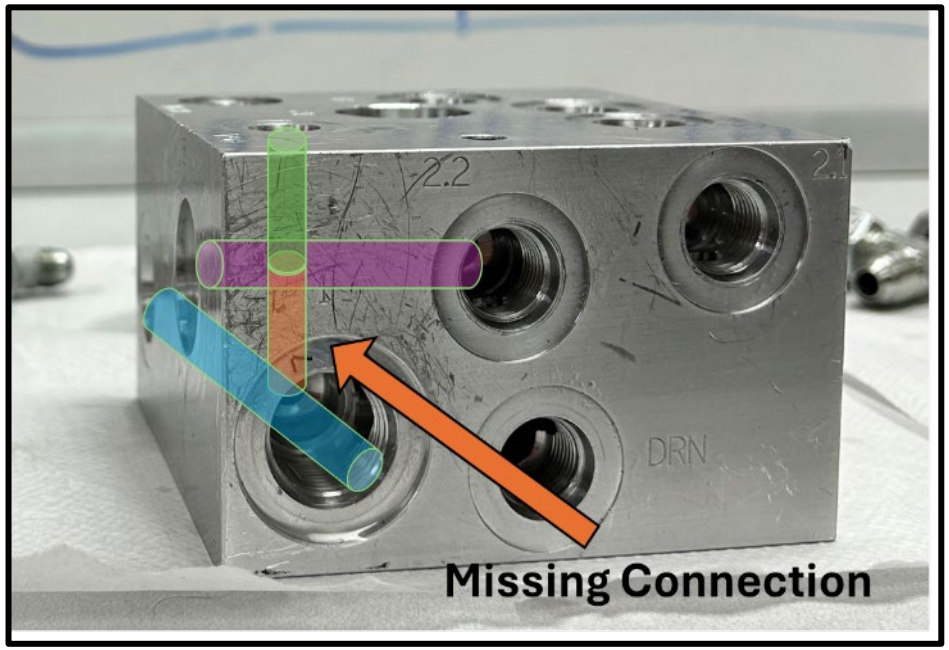
- Manifold CNC files showed there was a connection that was not drilled.



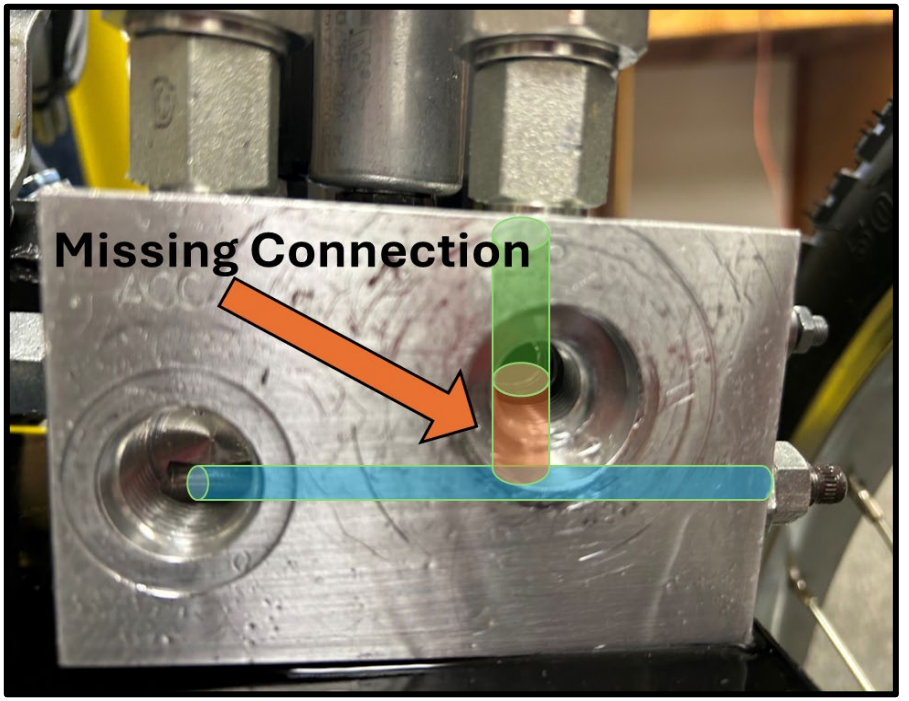


Manifold Connection Missing

Vehicle Testing



Manifold Sideview



Manifold Rearview

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Vehicle Testing

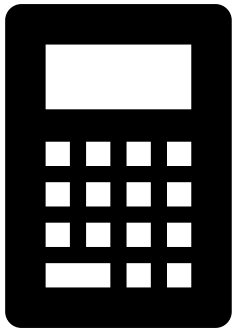
- The motor used through initial testing leaked due to a failure in the shaft seal

Motor shaft seal

Hydraulic Motor

Calculations

Spring 2024



Final Gear Ratios:

Pump-

36/9 ; 4/1 ratio

-greatly increasing rpm, increasing flow rate

Motor-

1. 9/20 : 20/24 ; .45/1 ; .83/1 ratios
2. 9/24 ; .375/1 ratio

- focused on increasing torque on the rear axel

Lessons Learned

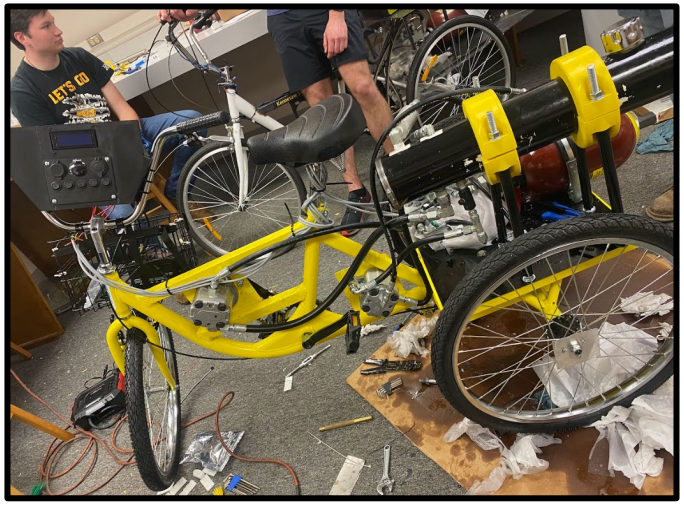
- Ask questions early
- Reach out to the local hydraulic shops
- Gear the motor ratio for torque instead of speed initially
- Ensure designed flow path matches machined parts
- Do not push your motor too hard when testing

Design Improvements

- Fail safe to direct drive
- Increased electronics complexity & functionality
- Created functional pneumatics with increased complexity
- Torque-driven gear ratios
- Improved aesthetics
- Fabrication completed weeks earlier to compensate for testing and optimization phase

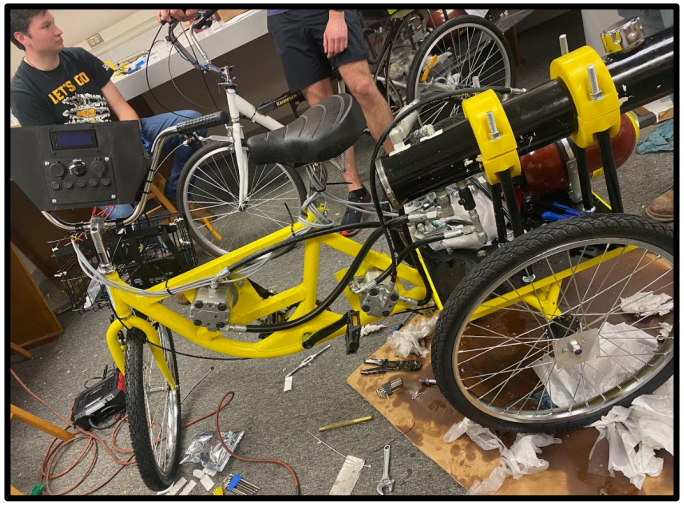
Design Choices Matter!

- Electronic choices conserved weight
- Reservoir choices conserved weight
- Pneumatic additions gave us torque and speed advantages
- Fail safe system to direct drive ensures we can compete in case of electrical issues



Design Choices Matter!

- Frame choice paid off
- Use of industry standard roller chain sprockets allowed for quick access to sprockets of varying numbers of teeth



Club Success

- Became a Registered Student Organization (RSO) at KSU in Fall 2023
- Had a successful first club meeting (online) with our guest speaker, Ernie Parker (February 1st)
- Had a successful in-person club meeting with Eric Cummings @ *Ross Controls* (February 23rd)
- Had a successful in-person club meeting with Cory Fisher @ *Sun Hydraulics* (April 2nd)

Acknowledgments

- Cory Fisher, *Sun Hydraulics*
- Ernie Parker, *International Fluid Power Society*
- Jared Amundson, *Norgren*
- Alex Greven, *HYDAC*
- Will Peterson & Alex Pruitt Redwine, *Hydraulic Supply Co*
- Mary Pluta, *NFPA*
- Holly Davis, *Office Manager KSU Mechanical Engr. Department*

Questions?

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