Fluid Power Vehicle Challenge

1st Place Overall Champion in National Fluid Power Vehicle Challenge

Jacob Landry, Ellen Rea, Angela Rodriguez, Sarah Smith and Naik Yusufi

Advisor: Bogdan Kozul

Washkewicz College of Engineering

Design Objectives

Vehicle Frame Design:
- Minimize Weight
- Integrate Component Mounts

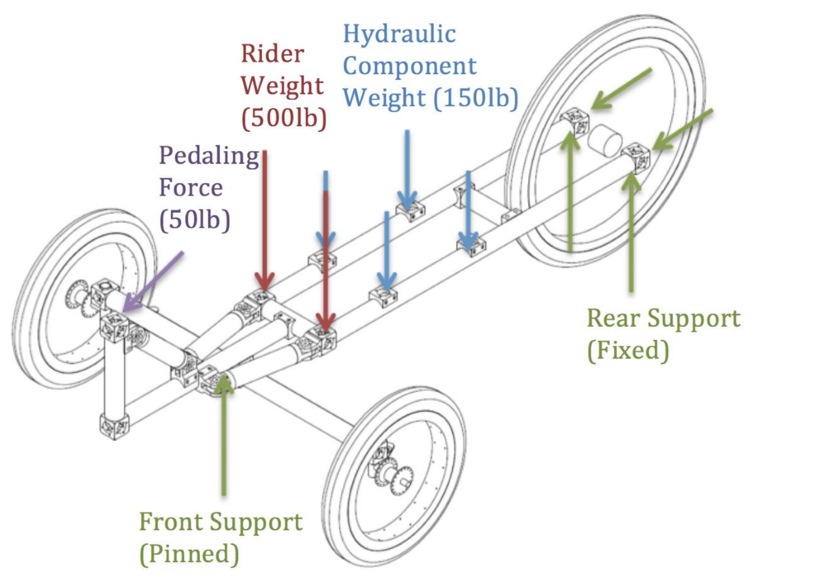
Design Steering System:
- Minimize Frictional Loss

Fluid Power System Design:
- Safe and User-Friendly Operation
- Charging Versatility
- Minimize Fluid Frictional Energy Loss

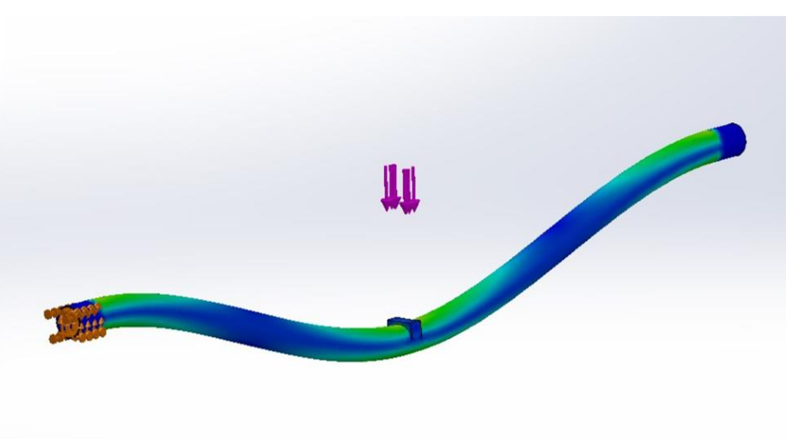
Electrical Interface Design:
- Ergonomic and Intuitive Controls

Custom Carbon Fiber Frame

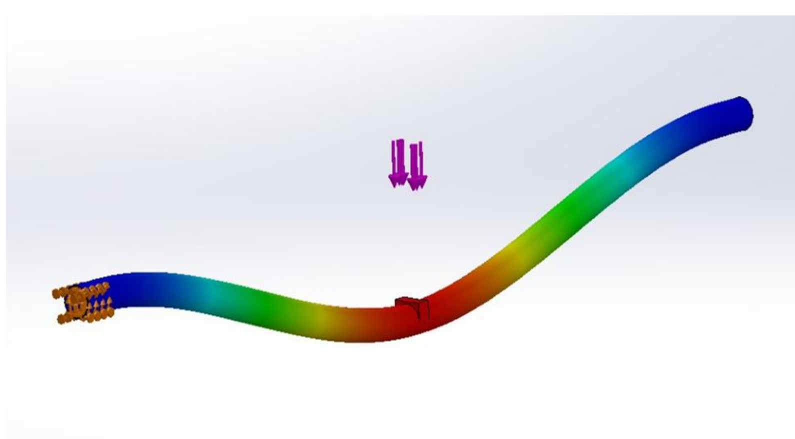
- Weight reduction was a top priority
- We designed and constructed a custom carbon fiber frame
- The modularity of the carbon tubing granted us flexibility in component mounting
- An FEA analysis was performed on a conservative model of the frame to verify the design



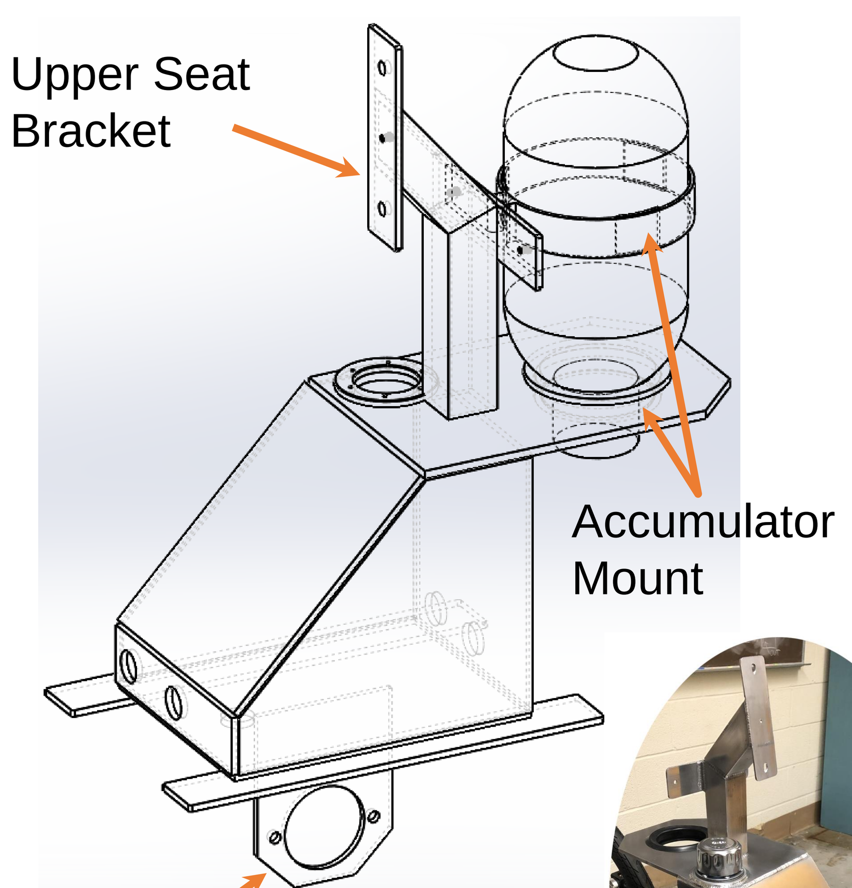
Maximum Stress: 70 MPa



Maximum Deflection: 3 mm



Integrated Hydraulic Reservoir



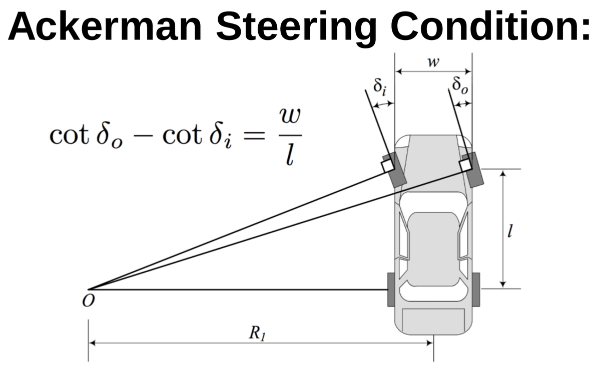
- Our new frame design included the integration of a custom 6061-T6 hydraulic reservoir into the vehicle frame
- In addition to being a structural component, the tank serves as a mount for the seat, accumulator and hydraulic motor
- This eliminates the need for several stand-alone brackets, which adds simplicity and reduces overall weight

Fabricating the Reservoir:

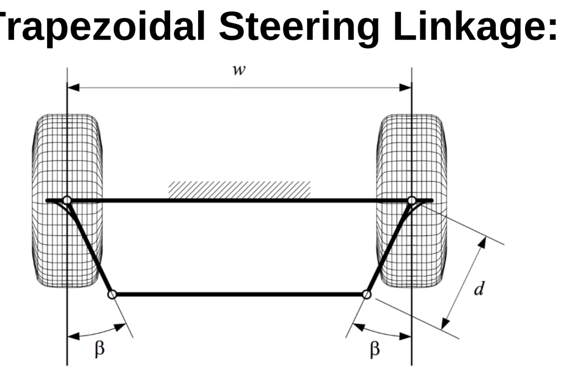
Optimized Steering Mechanism

Ackerman Steering Condition:

$$\cot \delta_o - \cot \delta_i = \frac{w}{l}$$



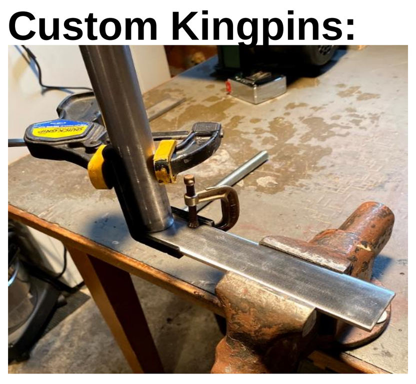
Trapezoidal Steering Linkage:



Jazar, R. N. (2019). Advanced Vehicle Dynamics. Cham: Springer International Publishing.

- We created a Matlab program to optimize our trapezoidal steering linkage design to closely approximate Ackerman steering
- The Ackerman condition dictates the relative wheel angles during turning to eliminate wheel slip
- This optimization improved our vehicle's efficiency by minimizing frictional energy losses associated with wheel slip

Custom Kingpins:



Steering Assembly:

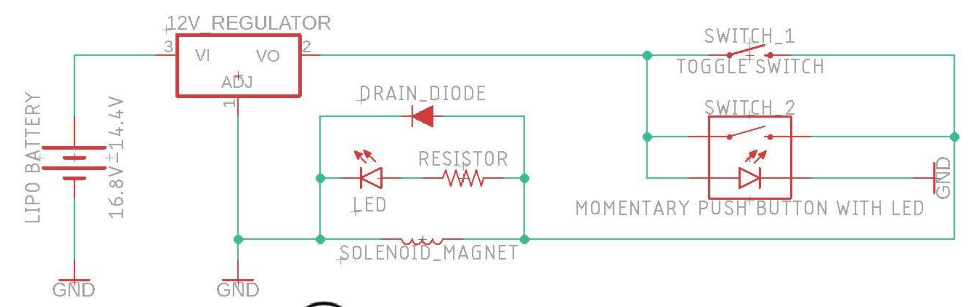
Versatile Hydraulic Circuit

- Our custom engineered hydraulic circuit gives the rider unprecedented versatility to charge the accumulator, including: pedal charging, auxiliary electrical charging and regenerative braking
- Ergonomic and safe design was achieved through implementing a solenoid valve and accompanying electrical circuit to allow the rider to regeneratively brake without taking their hands off the handlebars
- A robust and simple electrical circuit was created to actuate the solenoid valve. A high energy density, lithium polymer battery was selected to minimize weight

Handlebar Controls:

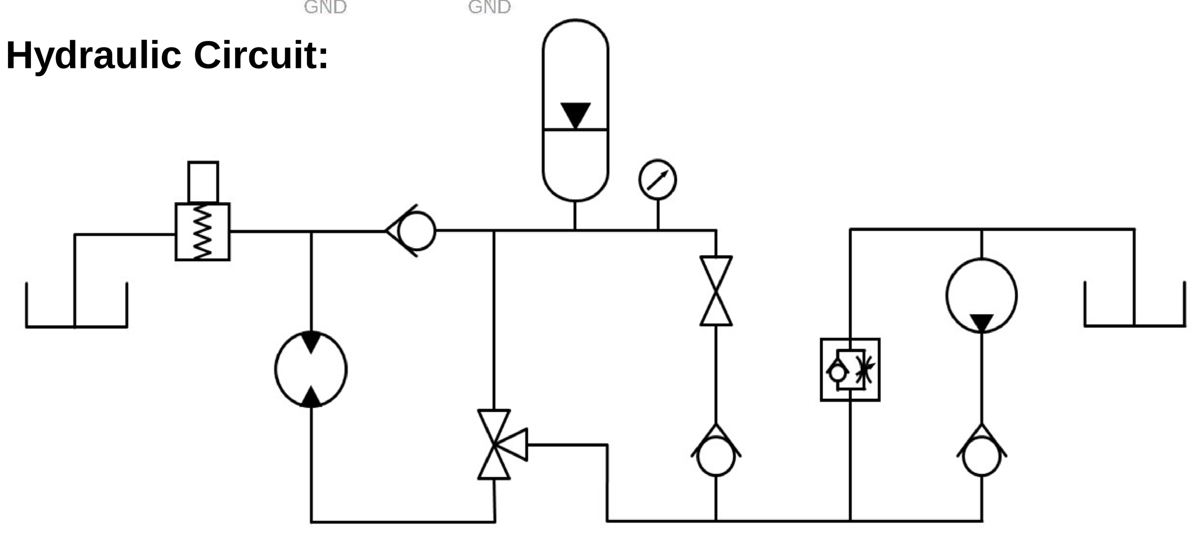
Solenoid Valve:

Electrical Circuit:



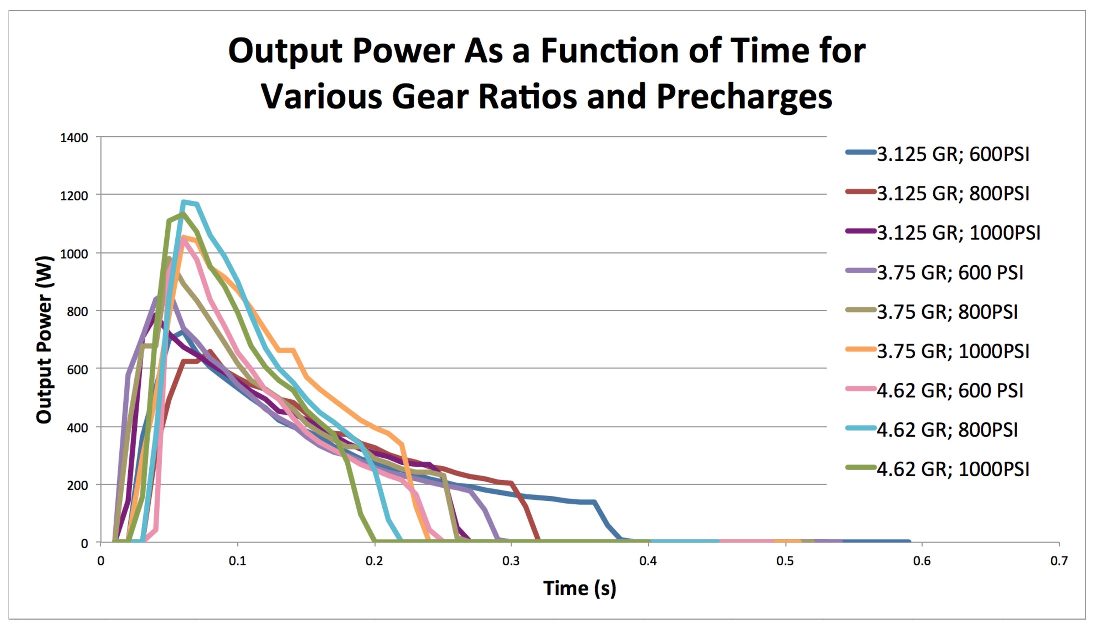
Main Operational Modes:
- Pedal (Direct) Drive
- Accumulator Drive
- Regenerative Braking
- Pedal Charge
- Auxiliary Electric Charge

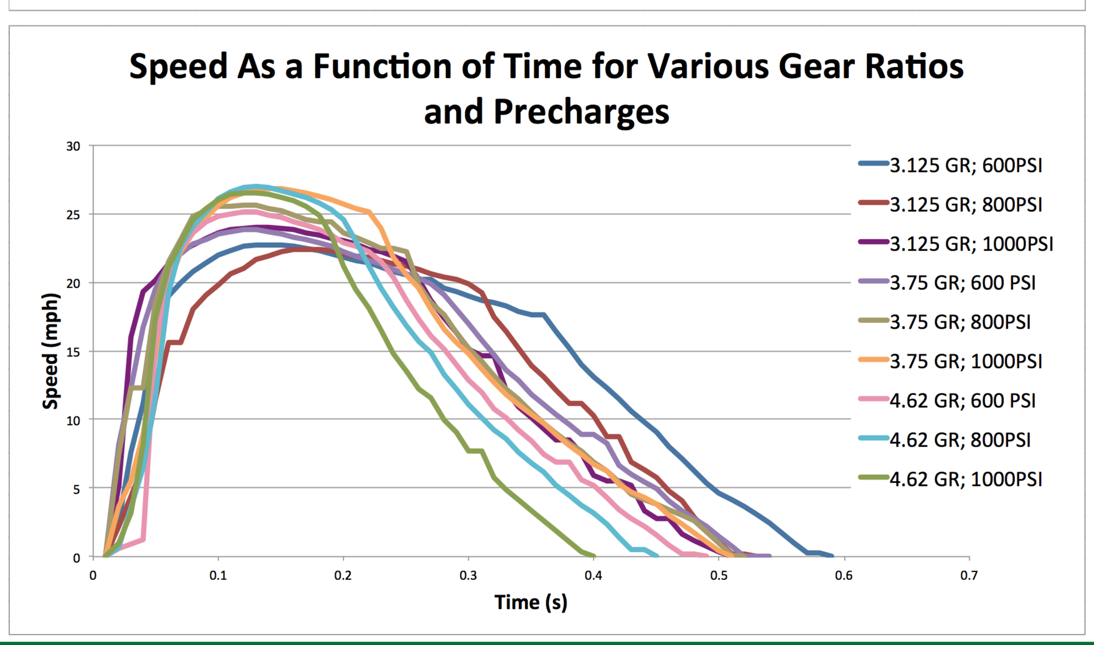
Hydraulic Circuit:



Power Output and Speed Testing

- Vehicle performance for various gear ratios and precharges was tested using a stationary power trainer
- The output power jumps up to a maximum and then decreases exponentially while the pressure in the accumulator drains
- The vehicle accelerates to a maximum speed and then begins decelerating as the power output declines. Once the accumulator is depleted, friction takes over and the vehicle coasts to a stop

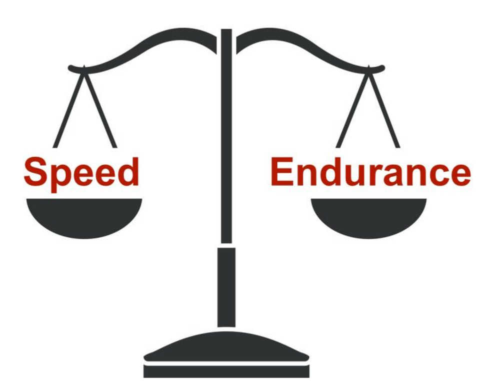


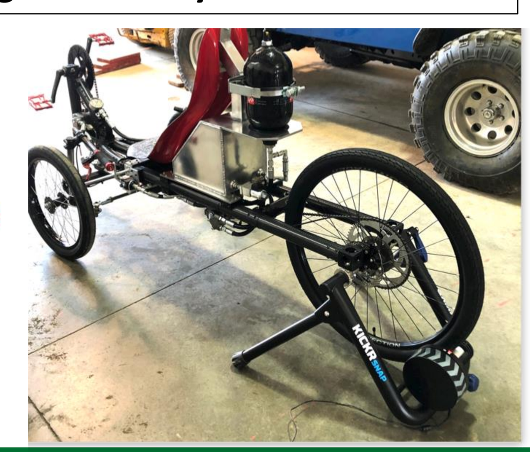


Increasing Gear Ratio:
- Increased torque exerted on the rear wheel leads to a steeper acceleration and allows the bike to reach a higher top speed
- Increased revolutions of the motor per revolution of the rear wheel lead to a higher flow rate which depletes the stored fluid faster

Increasing Precharge:
- An increase in average stored accumulator pressure increases stored energy
- The additional nitrogen in the accumulator decreases the usable oil volume which negatively impacts stored energy

With these effects in mind, a 3.75 rear end gear ratio and 1,000 psi precharge were selected to maximize top speed without sacrificing too heavily on endurance.





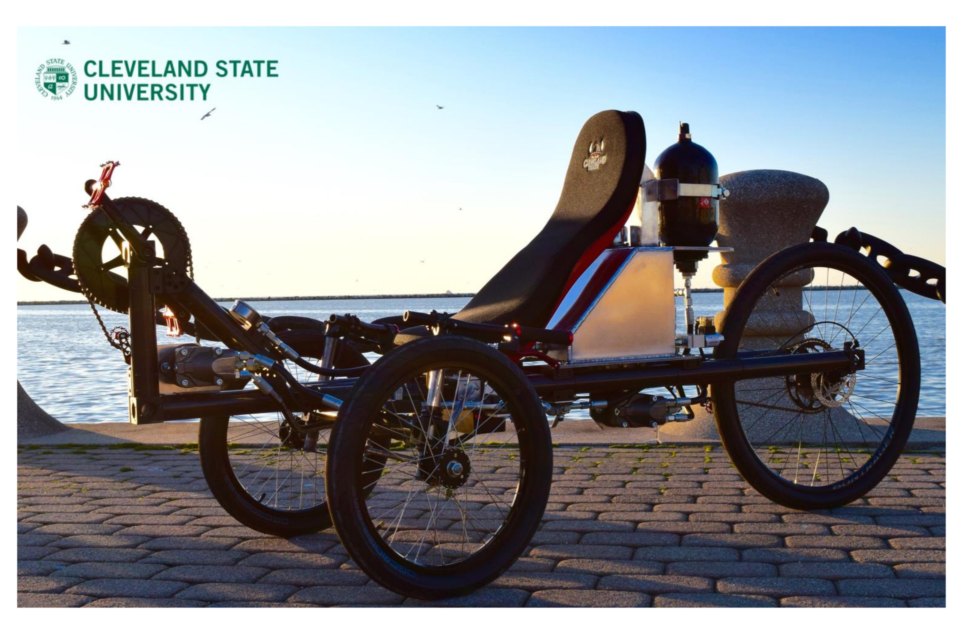
Final Vehicle and Competition

1st Place Overall Champion
2020 NFPA Fluid Powered Vehicle Challenge

Cleveland State University competed against 14 other universities from across the country including:

- Purdue University
- University of Cincinnati
- Iowa State University
- West Virginia Tech
- Milwaukee School of Engineering
- University of Akron
- Colorado State University
- Murray State University
- California Polytech
- Michigan Tech
- University of Denver
- Western Michigan University
- Arizona State University
- Purdue Northwestern

Final Vehicle Performance:



- **Top Speed: 27 mph**
- **Curb Weight: 171 lbs**
- **600 ft Sprint Time: 11.4 s**
- **Full Throttle Efficiency: 8%**

Acknowledgements

Special thanks and gratitude to Bogdan Kozul and George Germann for their tireless help and invaluable knowledge. We would also like to thank our sponsors: the National Fluid Power Association, Parker Hannifin, Corewire Ltd, WC Engineering, Bearing Services, Steelhead Composites, Rockwest Composites, Superior Beverage and DYO