

NFPA Fluid Power Vehicle Challenge - Hydraulic Human-Powered Vehicle

Team: Saud Albishi, Kushiban Alkushiban, Saad Alshamrani, Gregory Chekerdijan, Sebastian Cornejo, Luke Dedina, Vincent Phan, Treyce Pittman, Kyaw Swan Yee

Mentors: Jose M. Garcia, Richard Lyman

Problem Statement

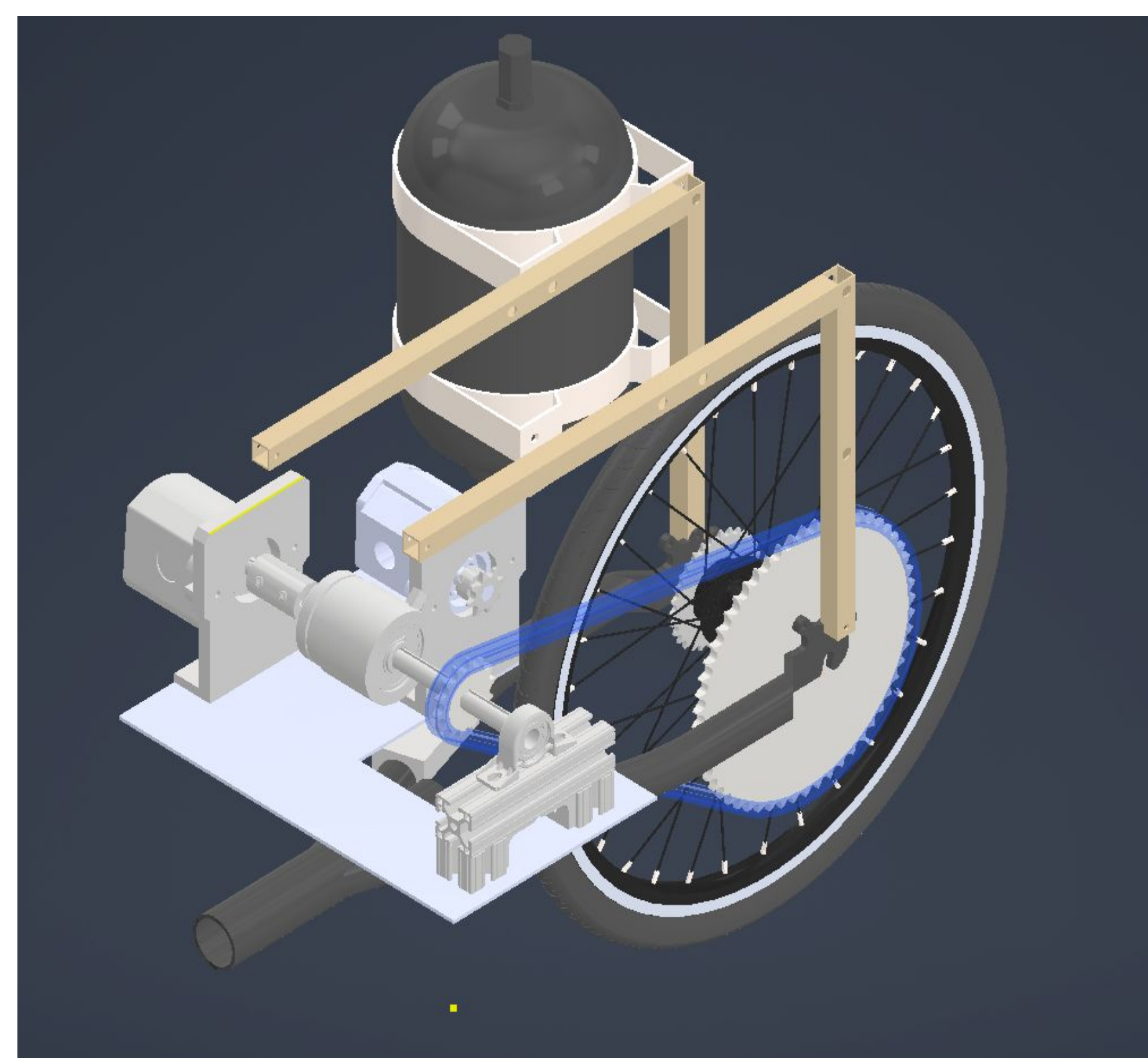
The Purdue Fluid Power Club's existing vehicle has an inefficient, heavy chassis and drivetrain that has hurt its performance at the NFPA Fluid Power Vehicle Challenge. The current clutch system lacks reliability, and the digital interface uses an unstable touchscreen that produces inaccurate speed data. The goal is to redesign the drivetrain, implement a pneumatic clutch engagement system, and build a fault-tolerant digital control interface to restore PFPC's competitiveness.

Customer Background

- Customer: Purdue Fluid Power Club (PFPC), competing in the NFPA Fluid Power Vehicle Challenge at IMI near Chicago
- Past results have ranged from 1st place finishes to receiving no awards
- NFPA rules require all energy to come from the rider, stored in hydraulic accumulators - making weight and efficiency critical

Requirements

- Vehicle weight must not exceed 80 lbs without a rider, verified by a calibrated scale
- Frame must be aluminum or steel with a sufficient factor of safety, confirmed through product specifications and calculations
- Bike must demonstrate reliable stopping performance, validated through brake tests on pavement
- Hydraulic brake system must use a piston design at or below 1,500 psi with no leaks, confirmed through pressure testing
- Full CAD model of the frame, drivetrain, and braking system required as a design deliverable



Final Design

- TerraTrike Maverick recumbent chassis purchased as the base and modified to support all hydraulic and drivetrain components
- Piston pump pedal system uses two double-acting hydraulic cylinders and a seesaw pedal bar to convert rider input into hydraulic pressure
- Pneumatic clutch connects a rotational hydraulic pump to the rear wheel, capturing braking energy and storing it in the accumulator for a boost
- Click PLC processes inputs from two hydraulic pressure sensors and a proximity speed sensor, displaying live PSI and MPH on an HMI screen
- Physical toggle switches control regeneration, accumulation, and boost modes, replacing the previous team's unreliable touchscreen interface



Experimentation and Concepts

Three concepts were explored and evaluated via weighted decision matrix:

Piston Pump Pedals - linear pedaling using hydraulic cylinders to eliminate inefficient rotational dead zones

Prebuilt Recumbent Trike (TerraTrike) - off-the-shelf chassis modified for hydraulic integration; winner of down selection for stability, cost, and reduced fab time

Accumulator Throttle / Human Generator - rider charges accumulator, throttle controls output (like a hybrid vehicle); rejected due to complexity and part availability

Selected design: TerraTrike Maverick chassis + piston pump pedal drivetrain + pneumatic clutch for regenerative braking



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Testing and Results



Preliminary Testing

Testing the vehicle before competitions showed promising results, but revealed some problem areas:

- Nitrogen bladder puncture in accumulator
- Leaky lines
- Supply line cavitation
- Boost solenoid leakage
- Inconsistent e-shifter

These issues were resolved before competing at IMI in Rockford, IL.

Competition Results

- Overall: Unreleased Currently (Improved From Last Year)
- Design Presentation: 3.93/5
- Regenerative braking test: Fail
- Efficiency Race: 1st Place (19.9%)
- Sprint Race: 2 min 11 sec
- Endurance Race: 9.5 Laps

