10 YEARS

NFPA

Fluid Power =VEHICLE Challenge

Final Presentation and Design Review

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NFPA
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Technology
Foundation

WESTERN MICHIGAN UNIVERSITY

The Team

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Previous Year Design

- The 2026 vehicle is based on a previous year's design
- Testing of previous year's bike revealed:
  - No control over hydraulic modes
  - Chain slipping and poor power transfer
  - Low torque from a broken gear hub

- Areas requiring improvement:

Safety

Drivetrain & Performance

Rider Controls

Regenerative Braking

Vehicle Design: Front Drivetrain

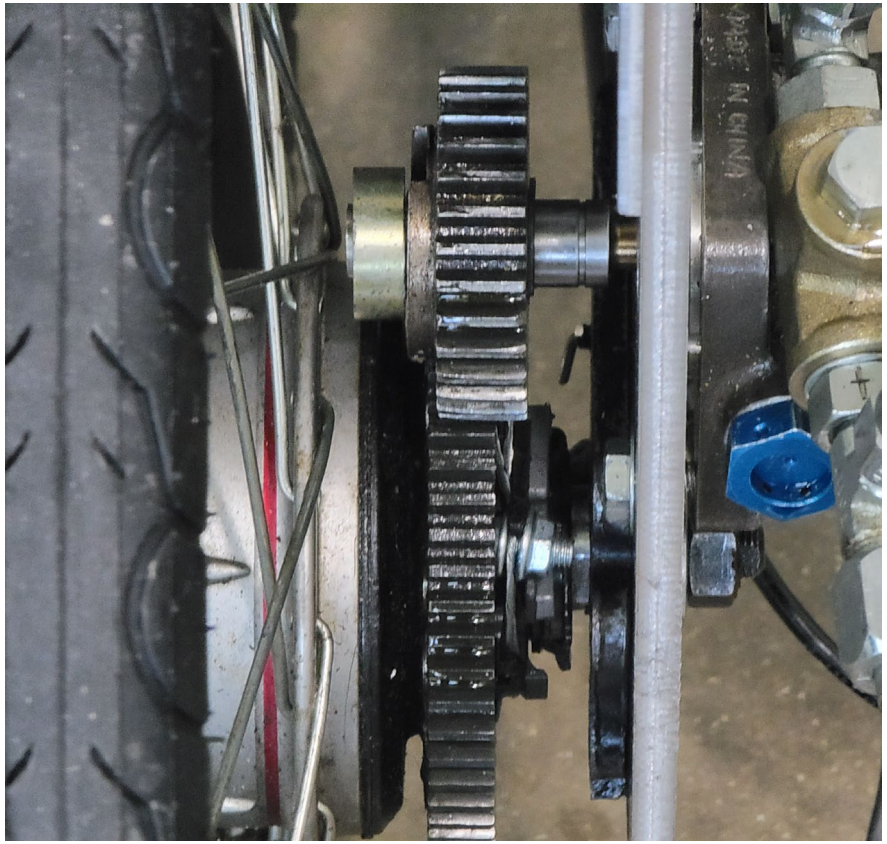
- Eliminated chain-slipping by increasing chain and sprocket size
- Repaired gear-hub, increasing range of torque and speeds
- Added chain/gear guards for safety

Old Chain & Sprocket

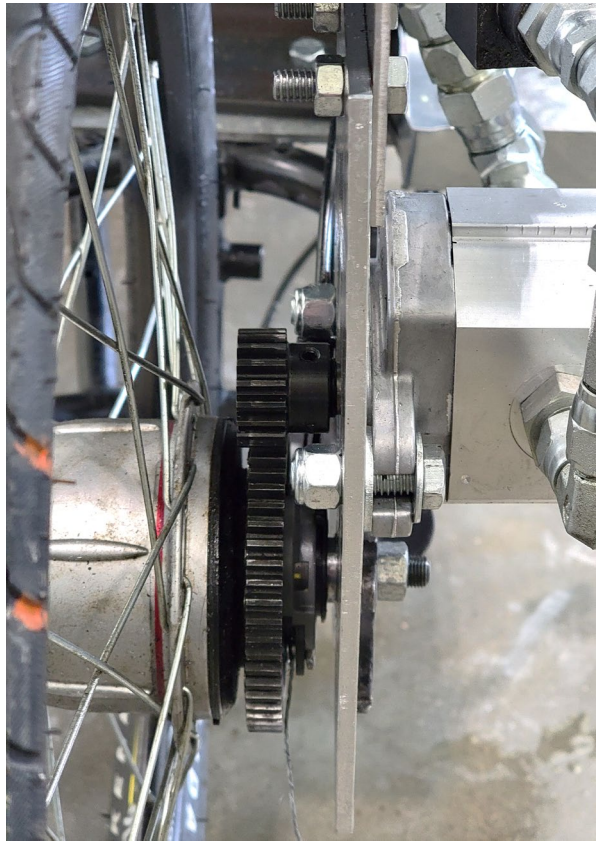
New Chain & Sprocket

Added Chain Guard

Vehicle Design: Rear Drivetrain



Old 2:1 Gear Ratio, and Old Motor



New 3.5:1 Gear Ratio, and New Motor

Vehicle Design: Rider Controls

- Control system was mounted to maximize leg room and ease of use
- Pressure gauges are nearby for easy pump/accumulator readings
- Valve connectors consolidated in a wrap to reduce snagging
- Manual override valves for power-off control or troubleshooting

Control System & Gauges

Valve Connector Consolidation

Vehicle Design: Hydraulic System

- Coast ball valve was added, allowing fluid to circulate between motor input & output
- Accumulator purge mounted for easy access near the manifold
- Line-bodies mounted to IPS frame, freeing up space for manifold

Coast Ball-Valve

Accumulator Purge

Line-body Mounting

Vehicle Testing

- Testing revealed:
  - Bike was easy to ride
  - Control system was easy to use
  - Decent cruise speeds but poor sprint times and low efficiency

- Changes to be made
  - Rubber to damp vibrations in chain guard
  - Loc-tite for motor gear set screws
  - Tighten hand-pump mount
  - Rubber on pedals for more grip

- Looking back at design objectives:
  - Tested top speed is 32% lower
  - Vehicle can overcome a 3% grade
  - A reasonable balance was achieved between torque and speed

Hard Pedaling		
Distance	80	ft
Time 1	6.35	s
Time 2	6.18	s
Time 3	6.1	s
AVG Speed	8.78	MPH
Cruising		
Distance	80	ft
Time 1	7.98	s
Time 2	8.05	s
Time 3	7.95	s
AVG Speed	6.82	MPH
Boosted Cruise		
Distance	80	ft
Time 1	5.85	s
Time 2	5.96	s
Time 3	6.04	s
AVG Speed	9.17	MPH

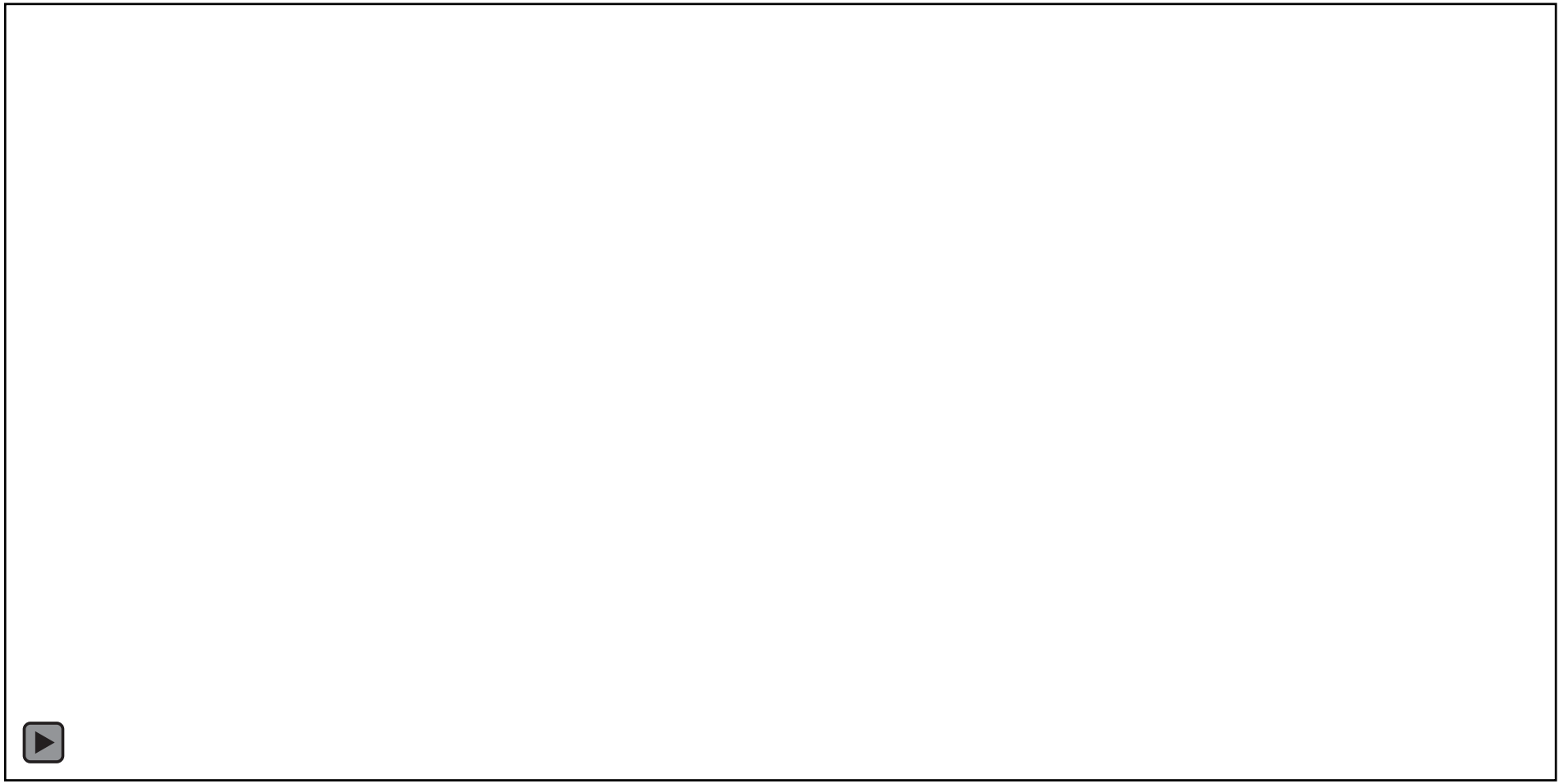
Efficiency Test		
Pressure	520	psi
Time	48	s
Distance	270	ft
Score	2.4	%

Sprint - Pedaling		
Distance	80	ft
Pressure	NA	psi
Time	18	s
Sprint - w/Boost		
Distance	80	ft
Pressure	520	psi
Time	18.2	s

Turn Radius		
Left	4	ft
Right	4	ft

Regen Braking Overview

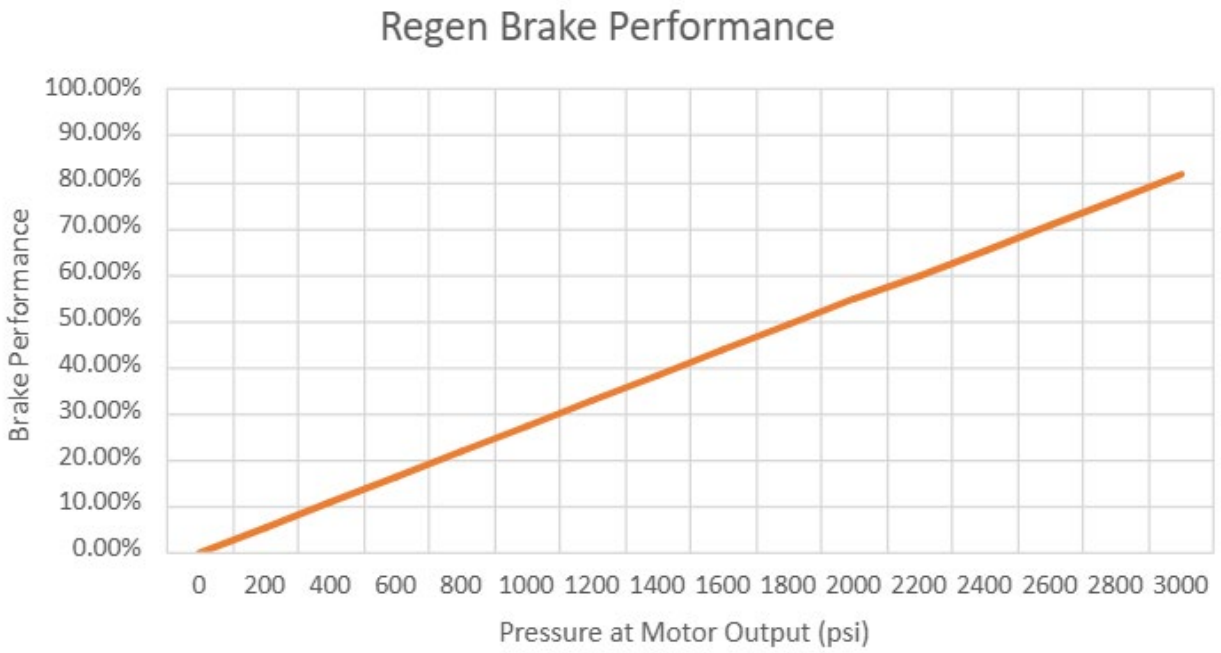
- Variable regenerative brake by using a proportional valve
- Allows to adjust braking for light braking or heavy braking down incline
- Closer feel to a mechanical bike brake



Regen Braking Performance

- How does this feel to the rider? Is variable control effective?
- Analysis was done to compare designed regen to normal bike braking
  - Total Weight 350lb
  - Typical bike deacceleration of 0.3 g's
  - Motor to wheel 4.5, motor displacement of 0.4 CIR

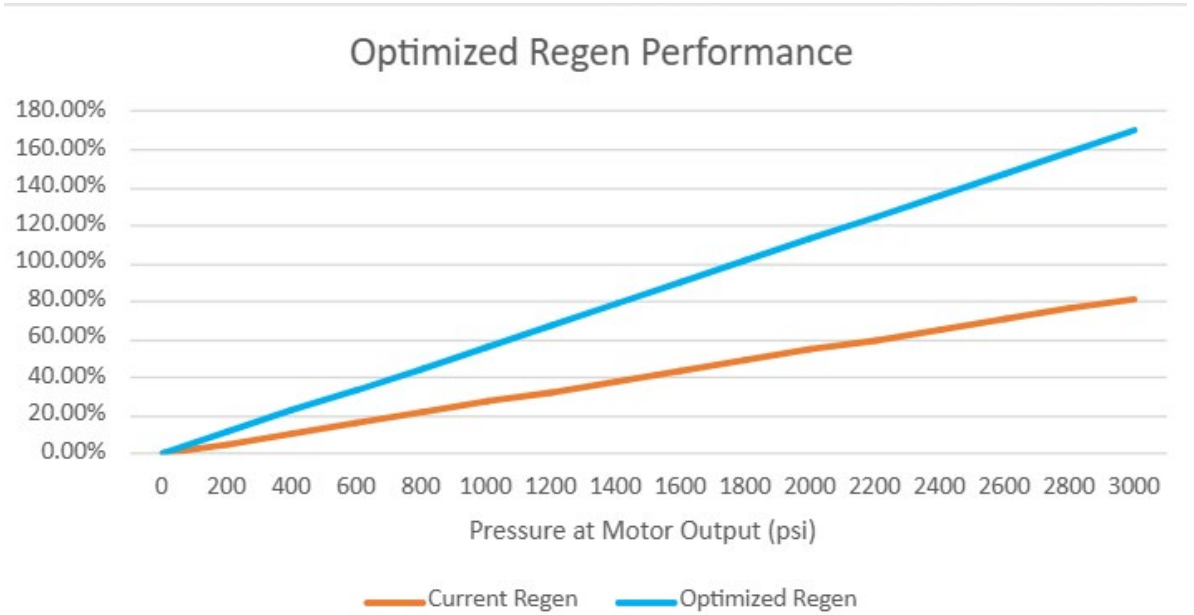
Accumulator Pressure (psi)	Motor Torque (lb*in)	Wheel Torque (lb*in)	Acceleration (ft/s^2)	Acceleration (MPH/s)	Performance (Accel./Typical)
0	0.0	0.0	0.0	0.0	0.00%
200	12.7	57.3	-0.5	-0.4	5.46%
400	25.5	114.6	-1.1	-0.7	10.91%
600	38.2	171.9	-1.6	-1.1	16.37%
800	50.9	229.2	-2.1	-1.4	21.83%
1000	63.7	286.5	-2.6	-1.8	27.28%
1200	76.4	343.8	-3.2	-2.2	32.74%
1400	89.1	401.1	-3.7	-2.5	38.20%
1600	101.9	458.4	-4.2	-2.9	43.66%
1800	114.6	515.7	-4.7	-3.2	49.11%
2000	127.3	573.0	-5.3	-3.6	54.57%
2200	140.1	630.3	-5.8	-4.0	60.03%
2400	152.8	687.6	-6.3	-4.3	65.48%
2600	165.5	744.9	-6.9	-4.7	70.94%
2800	178.3	802.2	-7.4	-5.0	76.40%
3000	191.0	859.5	-7.9	-5.4	81.85%



Regen Braking Findings

- Regen not enough for quick stops until accumulator approaches 3000psi
- This regen would function better for pacing

- Regen effectiveness can be doubled by
  - Increasing rear ratio from 4.5 to 8
  - Decreasing vehicle weight by 50lb
- Bike brake "feel" is achieved at 1700psi instead of >3000psi



Lessons Learned

- Proper wheel hub made it easier to stay in operating range
- Pump and motor directions dictate drivetrain layout
- Work with common and uncommon parts
- Redundancy and smart design choices lead to safer and easier operation down the road
- Testing revealed how much torque was needed vs theoretical from kinematics
- High pressure and low volume of accumulator fluid resulted in a jumpy boost vs a sustained boost

Q&A