10 YEARS NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation & Design Review

Kennesaw State University
Yuritzi Cazares, Taylor Cullinan, Sebastian Flores, Wesley Hathcox, Kevin Kellner & Andro Wincek

April 8th, 2026

Dr. Richard Ruhala & Dr. Laura Ruhala

Outline of Presentation

- Team Introductions
- Design Choices and Comparison
- Vehicle Analyses and Construction
- Vehicle Testing
- Final Vehicle
- Lessons Learned and Q&A
- Acknowledgements

Outline of Presentation

- **Team Introductions**
- Design Choices and Comparison
- Vehicle Analyses and Construction
- Vehicle Testing
- Final Vehicle
- Lessons Learned and Q&A
- Acknowledgements

Team Introductions

Yuritzi Cazares
Project Manager

Taylor Cullinan
System Design

Sebastian Flores
Pneumatic Design and Component Selection

Kevin Kellner
Electronics and Programming

Wesley Hathcox *(MET)*
Construction and Testing

Andro Wincek
Construction and Testing

Team Introductions

Dr. Laura Ruhala
Advisor
Asst. Dept. Chair
Mechanical Engineering
KSU

Dr. Richard Ruhala
Advisor
Professor of
Mechanical
Engineering KSU

Richard Kennedy
Advisor
Professor of Mechanical
Engineering Technology
KSU

Richard Woodruff
Mentor
SunSource

Steve Gluck
Liaison
Fluid Power Instructor

Ernie Parker
Liaison
International Fluid
Power Society

Jake Anton
MET Student
Construction and Testing

TJ Lovelace
MET Student
Electronics and Testing

Owen Nelson
MET Student
Construction and Design

Jennifer Rosales
ME Student
Construction and Pneumatics

Outline of Presentation

- Team Introductions
- **Design Choices and Comparison**
- Vehicle Analyses and Construction
- Vehicle Testing
- Final Vehicle
- Lessons Learned and Q&A
- Acknowledgements

2025 vs 2026 Vehicle Design

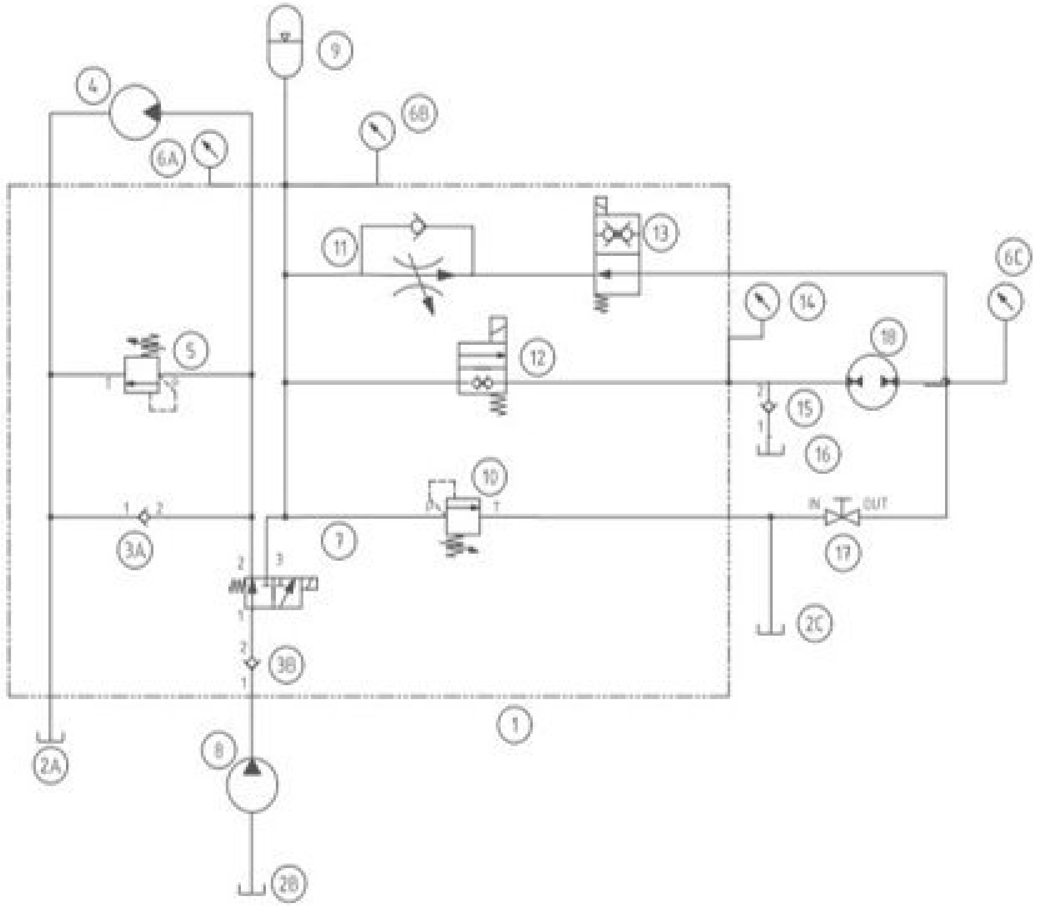
2024-2025

1. One Gear Ratio
2. Tricycle Reused from 2024
3. Dual Motor
4. Pneumatic Clutch

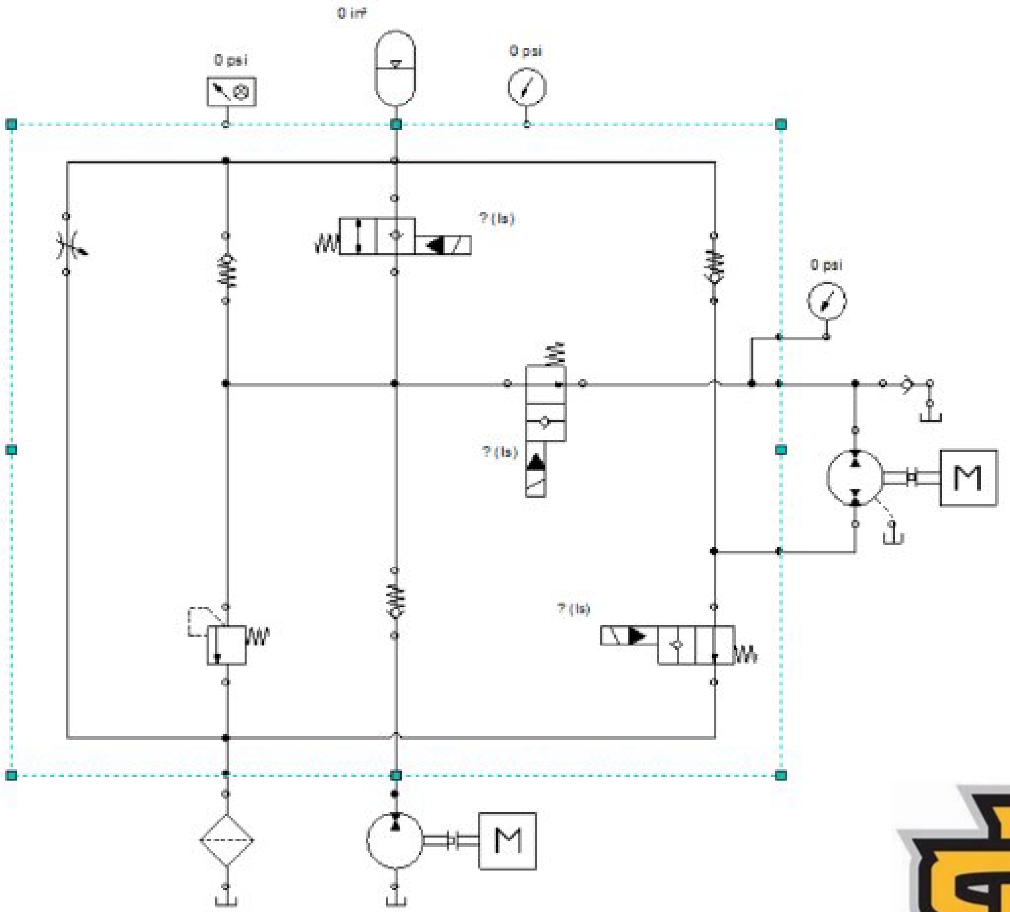
2025-2026

1. Pinion Internal Pedal Gearbox
   1. Optimized Gear Ratios
2. Bicycle Configuration
3. Bi-directional Motor for Regen
4. Pneumatic Training Wheels

2025 vs 2026 Hydraulic Circuit



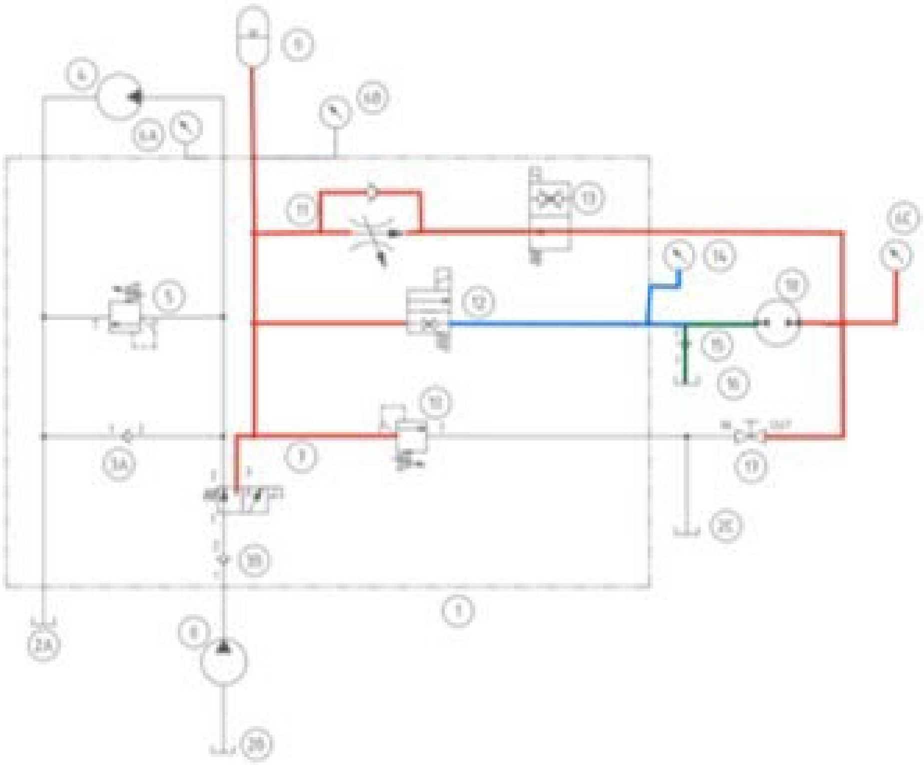
2025 Hydraulic Circuit



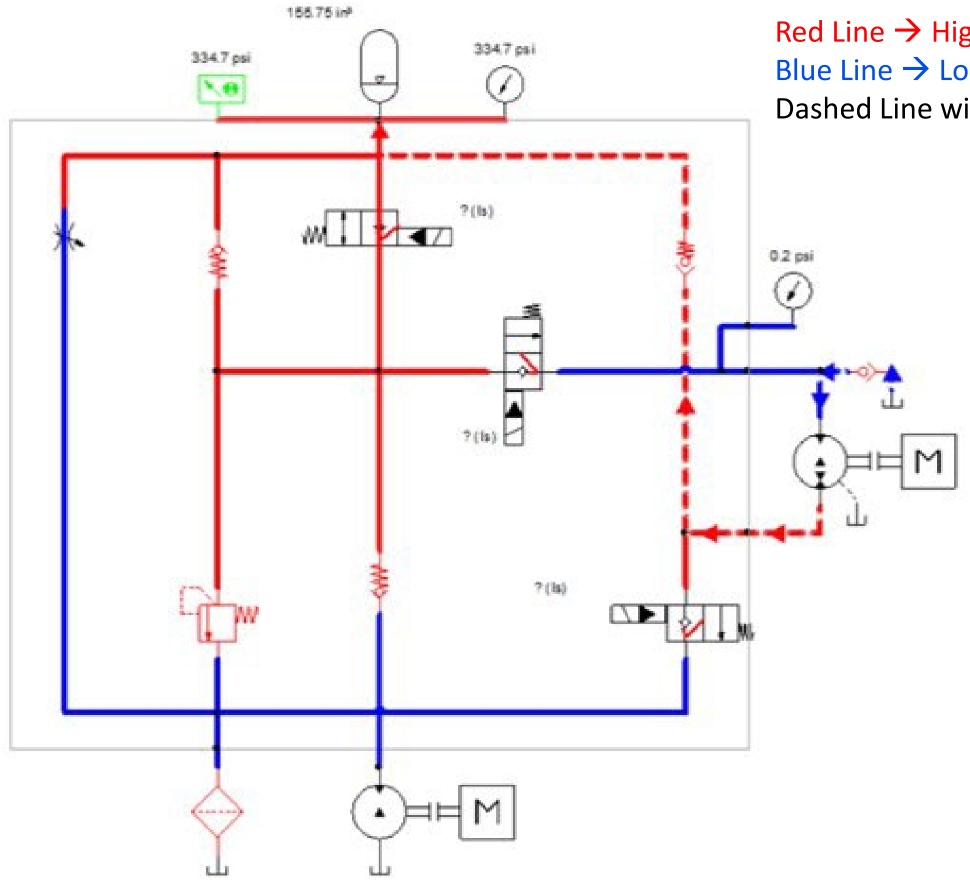
2026 Hydraulic Circuit

Regenerative Braking Circuit Comparison

Red Line → High-Pressure
Blue Line → Low-Pressure
Dashed Line with Arrows → Flow Path



2024-2025



2025-2026

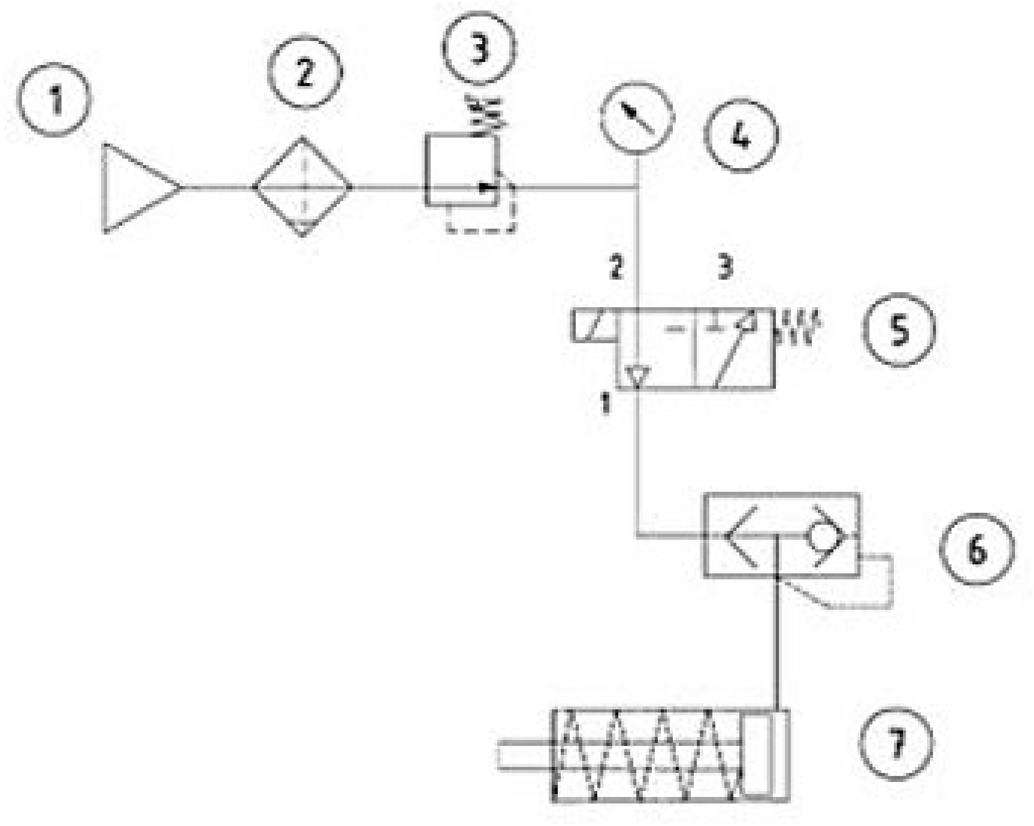
Hydraulic BOM

Part	Sizing	Price
Pump	IFP: 0.0854 in^3/rev SAE –8 inlet, SAE –6 outlet ½ in shaft, SAE AA 2-bolt mount	$146.90
Bidirectional Motor	SunSource/Danfoss: 0.513 in^3/rev Bi-rotational w/ external drain	$434.00
PVC Reservoir	6" diameter PVC 1 gal capacity	$45.00
Bladder Accumulator	1 gallon	Reused from previous year

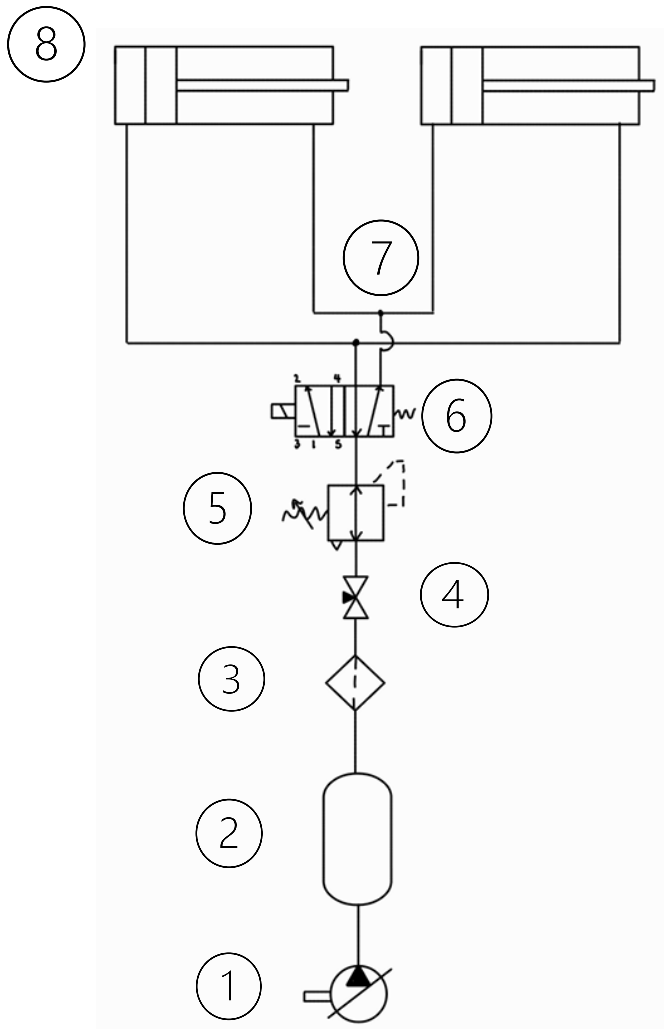
0.0854 CIR Gear Pump

0.513 CIR Gear Motor

2025 vs 2026 Pneumatic Circuit



2025 Pneumatic Clutch Design



2026 Pneumatic Training Wheels Design

1. Compressor
2. Tank
3. Filter
4. Shut off valve
5. Regulator
6. 5/2 valve
7. T-fitting
8. Double acting cylinders

Pneumatic BOM

Part	Sizing	Sustainability
Double Acting Cylinders x2	1.227" 250 psi max	New
Air Tank	0.5 gal	Re-used
5/2 Valve	116 psi max	New
Regulator	130 psi max	New
Filter	5-micron filter	Re-used
Shut Off Valve	250 psi max	New
T Fitting x2	250 psi max	New

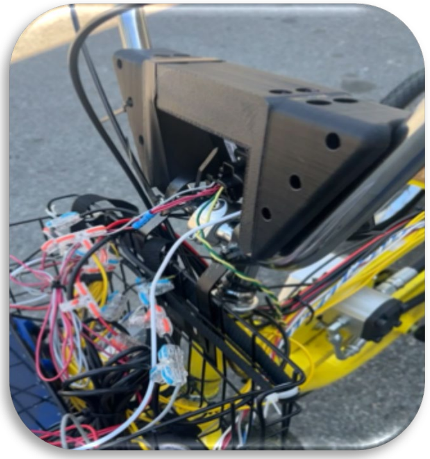
5-Micron Filter

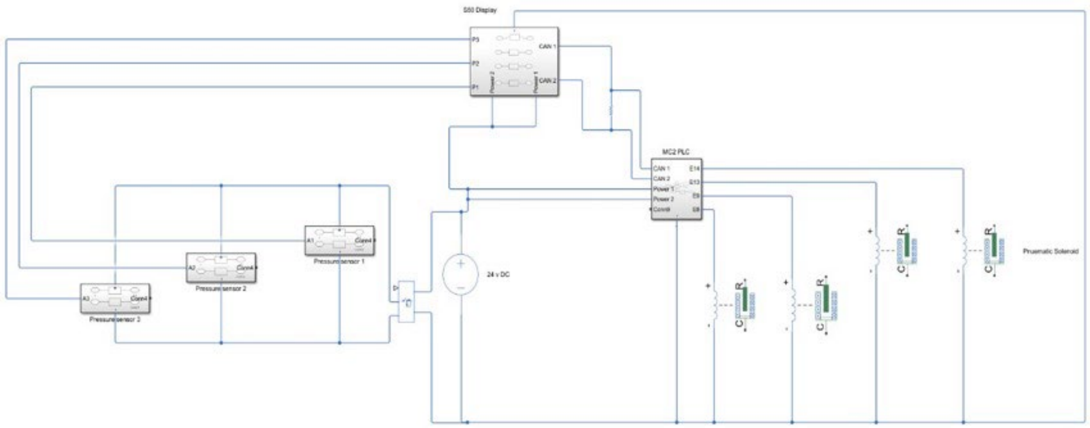
Example: 1.05 gal Pneumatic Air Tank

5/2 Valve

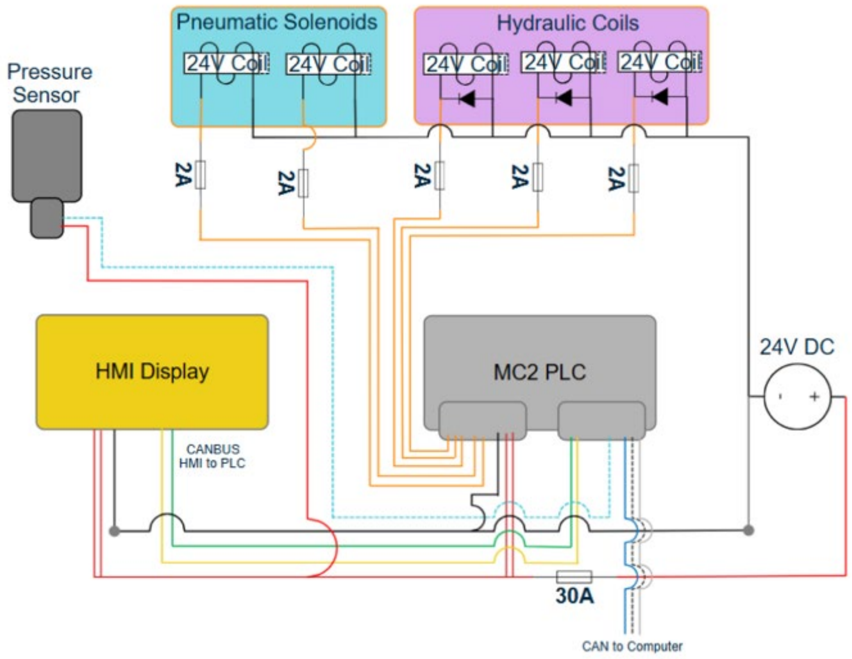
Double Acting Pneumatic Cylinder

2025 vs 2026 Electronics Circuit





2025 Electronics



2026 Electronics

2026 Electronics Display and Mount

3D Printed PLA Mount

2026 Electronics Code

```
IF BOOL_S50_1 THEN
    iMode := 1;
END_IF
IF BOOL_S50_2 THEN
    iMode :=2;
END_IF
IF BOOL_S50_3 THEN
    iMode :=3;
END_IF
IF NOT(BOOL_S50_3 AND BOOL_S50_2 AND BOOL_S50_1) THEN
    iMode := 0;
END_IF
```

Case Logic

```
CASE iMode OF
    0: //Direct Drive
    oSolonoid1 := FALSE;
    oSolonoid2 := FALSE;
    oSolonoid3 := FALSE;
    BOOL_MC2_1 := TRUE;

    1: //Accumulation Charge
    oSolonoid1 := TRUE;
    oSolonoid2 := TRUE;
    oSolonoid3 := TRUE;
    BOOL_MC2_1 := FALSE;

    2: //Accumulation Drive
    oSolonoid1 := TRUE;
    oSolonoid2 := FALSE;
    oSolonoid3 := FALSE;
    BOOL_MC2_1 := FALSE;

    3: //Regen
    oSolonoid1 := FALSE;
    oSolonoid2 := TRUE;
    oSolonoid3 := TRUE;
    BOOL_MC2_1 := FALSE;
END_CASE
```

Bike Modes

```
IF (BOOL_S50_4=TRUE)THEN
    oSolonoidAir1 := TRUE;
    oSolonoidAir2 := FALSE;
ELSE
    oSolonoidAir1 := FALSE;
    oSolonoidAir2 := TRUE;
END_IF

IF (UpdatedPressure>=1700)THEN
    BOOL_MC2_5 := FALSE;
    BOOL_MC2_6 := TRUE;
    BOOL_MC2_7 := FALSE;
ELSIF (UpdatedPressure>1200 AND UpdatedPressure<1700)THEN
    BOOL_MC2_5 := TRUE;
    BOOL_MC2_6 := FALSE;
    BOOL_MC2_7 := FALSE;
ELSE
    BOOL_MC2_5 := FALSE;
    BOOL_MC2_6 := FALSE;
    BOOL_MC2_7 := TRUE;
END_IF
```

Pneumatic and Pressure Logic

Outline of Presentation

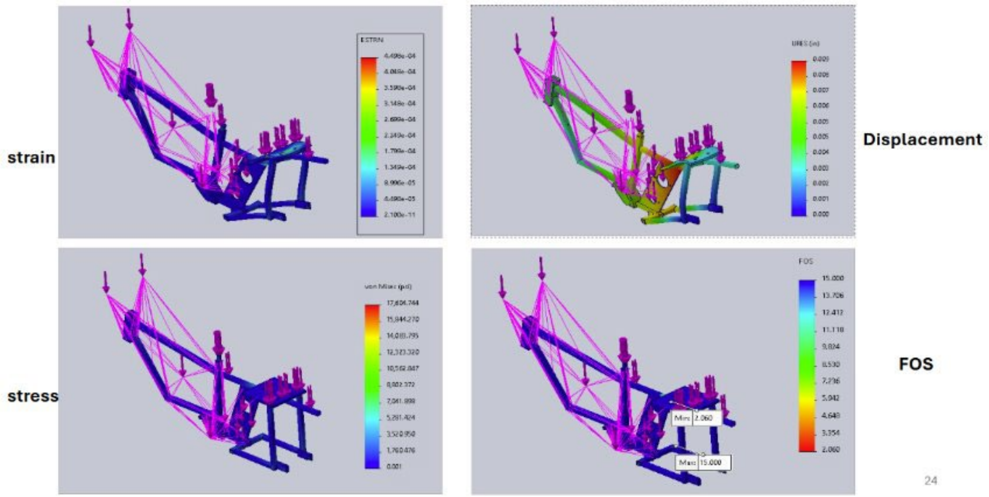
- Team Introductions
- Design Choices and Comparison
- **Vehicle Analyses and Construction**
- Vehicle Testing
- Final Vehicle
- Lessons Learned and Q&A
- Acknowledgments

Vehicle Analyses

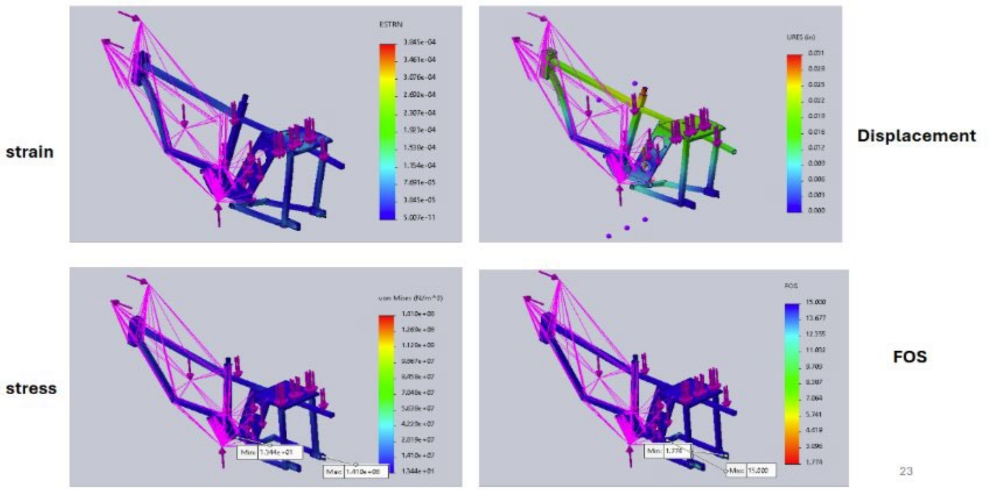
max motor torque (lb-in	teeth	pitch	PD	pitch radius (in)	pull on chain (lb)
239	10	0.5	1.62	0.81	295.43
239	60	0.5	9.60	4.80	49.79
239	14	0.5	2.25	1.12	212.73
239	17	0.5	2.72	1.36	175.67
avg wheel torque (lb-in)	teeth	pitch	PD	pitch radius (in)	pull on chain (lb)
842	10	0.5	1.62	0.81	1040.79
842	60	0.5	9.70	4.85	173.61
842	14	0.5	2.25	1.12	749.44
842	17	0.5	2.72	1.36	618.89
max push on pedals	pedal level length	diameter	radius	lbs pull on chain	
74	6.5	8.28	4.14	116.17	52 tooth
74	6.5	1.46	0.73	658.00	9 tooth
avg push on pedals	pedal level length	diameter	radius	lbs pull on chain	
39.25	6.5	8.28	4.14	61.62	52 tooth
39.25	6.5	1.46	0.73	349.01	9 tooth

Bike Chain Tension Calculations

FEA Case Study 2: Sitting without pedaling



FEA Case Study 1: Torsional



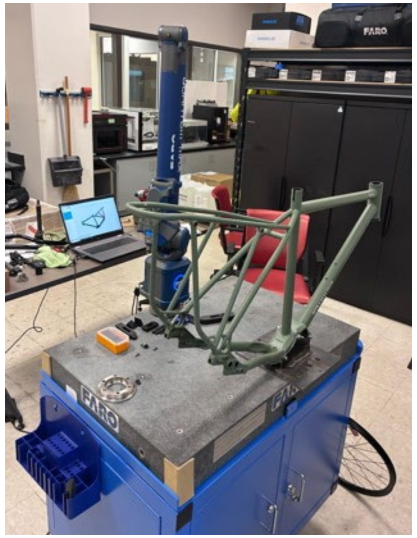
Vehicle Construction

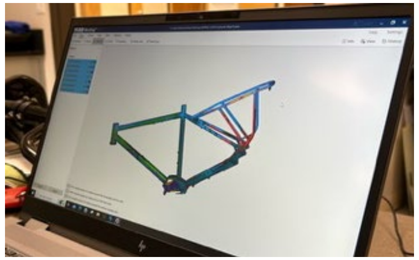
December 2025

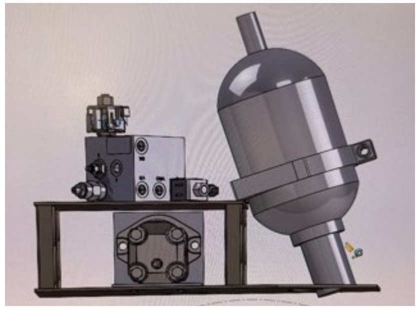
Late January 2026

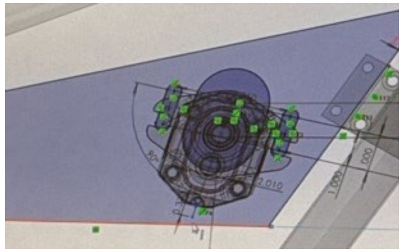
February 2026

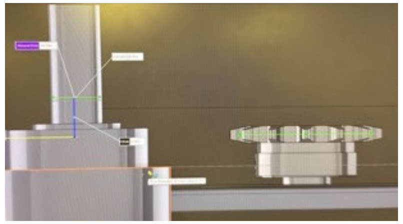
Early March 2026





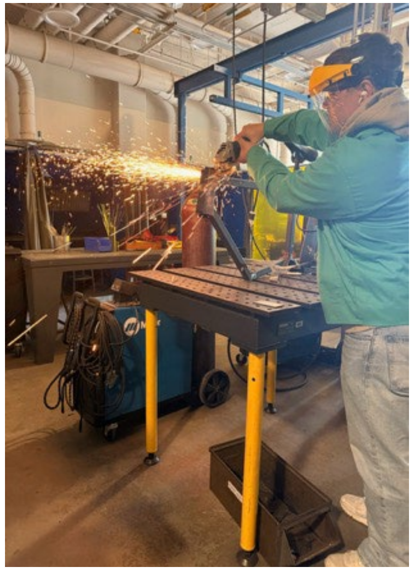


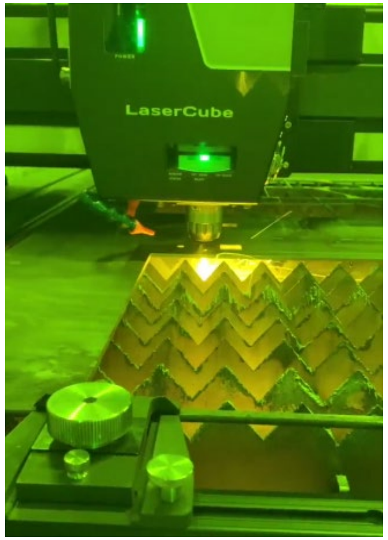




Vehicle Construction Continued...

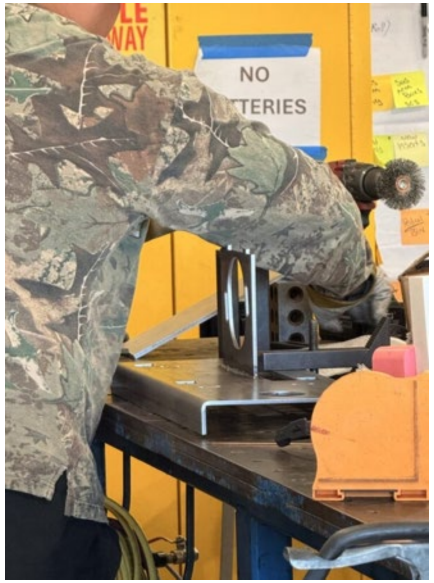
Mid-March 2026





Vehicle Construction Continued...

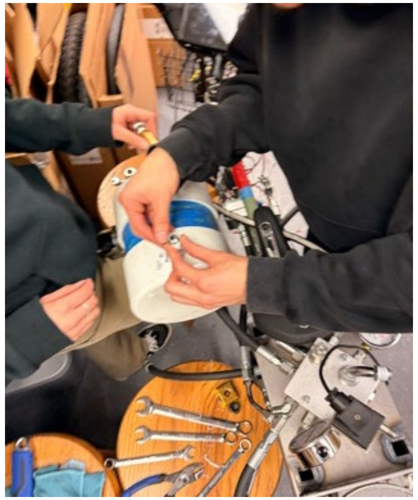
Late-March 2026












Outline of Presentation

- Team Introductions
- Design Choices and Comparison
- Vehicle Analyses and Construction
- **Vehicle Testing**
- Final Vehicle
- Lessons Learned and Q&A
- Acknowledgements

Vehicle Testing

Initial Test – March 30th

- Issue with training wheel stability
- Pump-to-pedal: 9-52
- Motor-to-back wheel: 15-60
- Regenerative braking works
- Accumulator charge and discharge work
- Hardwork in direct drive for little speed

Direct Drive

- Pump-to-pedal: 9-52
- Motor-to-back wheel: 10-60
- Avg speed: 2.78 mph

Regenerative Braking

- Pump-to-pedal: 9-52
- Motor-to-back wheel: 10-60
- 16 mph

March 31st

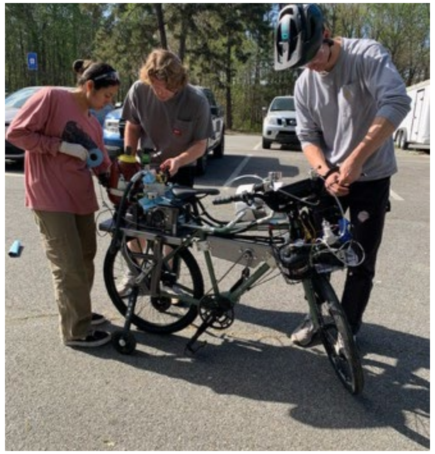
Sprint

Pump-to-pedal: 10-44
Motor-to-back wheel: 15-60

Pressure (PSI)	Top Speed (mph)
1700	15.7
1667.8	11

Pump-to-pedal: 10-44
Motor-to-back wheel: 15-60

Pressure (PSI)	Top Speed (mph)
1800	17
1500	11
1950	17



Vehicle Testing Continued

April 1st

Sprint

- Pump-to-pedal: 9-52
- Motor-to-back wheel: 10-17

Direct Drive

- Pump-to-pedal: 9-52
- Motor-to-back wheel: 10-17
- Top speed: 7 mph
- Avg speed: 5-6 mph

April 3rd

Direct Drive

- Pump-to-pedal: 9-52
- Motor-to-back wheel: 15-17
- Top speed: 12 mph
- Avg speed: 10 mph

April 4th

Sprint

Pump-to-pedal: 9-52

Motor-to-back wheel: 10-60

Pressure (PSI)	Top Speed (mph)
1800	17
2000	20

Vehicle Testing Continued

<u>Direct Drive = Endurance Race</u>

Changes Made:

- Gear ratio optimization – motor to back wheel - to improve efficiency
- Gear ratio optimization – pump to pedal - to make easier for rider

Result:

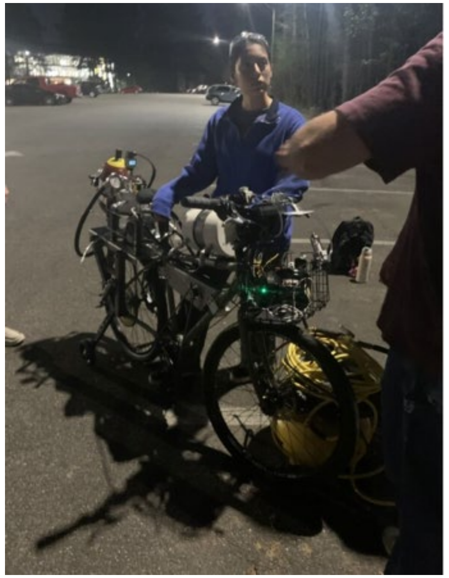
- 2.78 mph to 12 mph

<u>Regenerative Braking</u>

Change Made: Start at higher initial speed

Result:

- 11 feet
- 13 feet



<u>Accumulator Drive = Sprint Race</u>

Change Made: Gear ratio optimization

Result:

- 11 mph
- 17 mph
- 20 mph

Outline of Presentation

- Team Introductions
- Design Choices and Comparison
- Vehicle Analyses and Construction
- Vehicle Testing
- **Final Vehicle**
- Lessons Learned and Q&A
- Acknowledgements

Final Design

Starting Over Finalized Bike

67 Days

Outline of Presentation

- Team Introductions
- Design Choices and Comparison
- Vehicle Analyses and Construction
- Vehicle Testing
- Final Vehicle
- **Lessons Learned and Q&A**
- Acknowledgements

Lessons Learned and Q&A

- Don’t have 2 design teams serially dependent. Failure of Team A’s frame affected component placement of Team B. Choose a frame early
- Design and Manufacturability
- No matter how early you start, it's never early enough
- Major setbacks are inevitable, anticipate delays
- Don't lose hope!

Outline of Presentation

- Team Introductions
- Design Choices and Comparison
- Vehicle Analyses and Construction
- Vehicle Testing
- Final Vehicle
- Lessons Learned and Q&A
- **Acknowledgments**

Acknowledgements

Dr. Laura Ruhala and **Dr. Richard Ruhala,** KSU Mechanical Engineering

Steve Gluck, **Ernie Parker**, and **Richard Woodruff**

TJ Lovelace, Owen Nelson, Jake Anton, and **Jennifer Rosales**

Mary Pluta, National Fluid Power Association

Holly Davis, KSU Mechanical Engineering Office Manager

Richard Kennedy, KSU Mechanical Engineering Technology

Dr. Patrick Opdenbosch, KSU Mechanical Engineering

HSC

IFP

IMI

SunSource

Richard Serrano

Marc Seemann, Pinion

Trinity Hunt, **David Olusayana**, **Elsy Ramos**, and **Ashton Wiley**

Cycology Bike Shop

Jordan Liebel