NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation
The Incompressibles
Cal Poly - San Luis Obispo
Dr. James Widmann
April 3, 2019

Team Intro

Nicholas Gholdoian

David Vitt

Kyle Franck

Alex Knickerbocker

Julian Rodkiewicz

Russell Posin

Agenda

1. Design Overview
2. Frame
3. Drivetrains
4. Mechatronics
5. Manufacturing
6. Testing
7. Lessons Learned

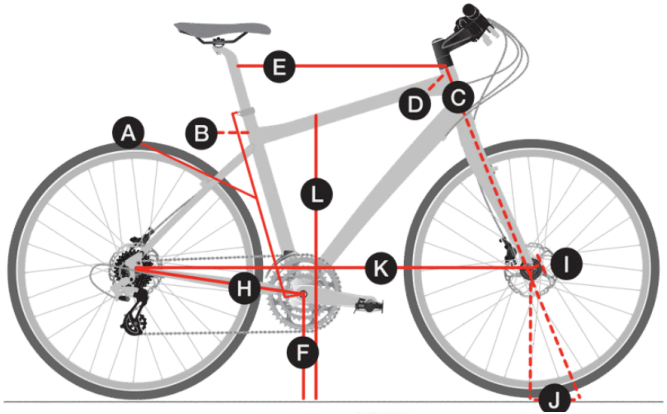
Design Overview

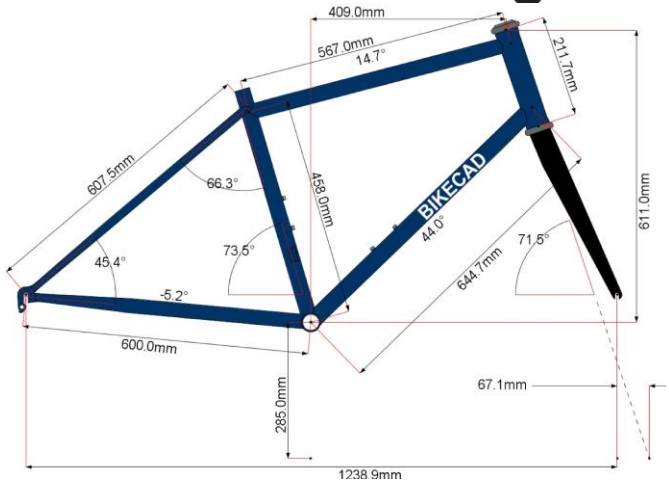
- Custom steel frame
- Sun-source manifold
- Right angle planetary gearbox
- 2-speed front drivetrain
- Welded aluminum reservoir
- 1 gallon composite accumulator
- Custom mechatronics system
- Bosch AF2O-5 pumps

Frame

Modeled after Trek FX Sport 4 (Large)

- Hybrid/cross country
- Comfort/sport
- 700C x 32C tire
- Steel construction

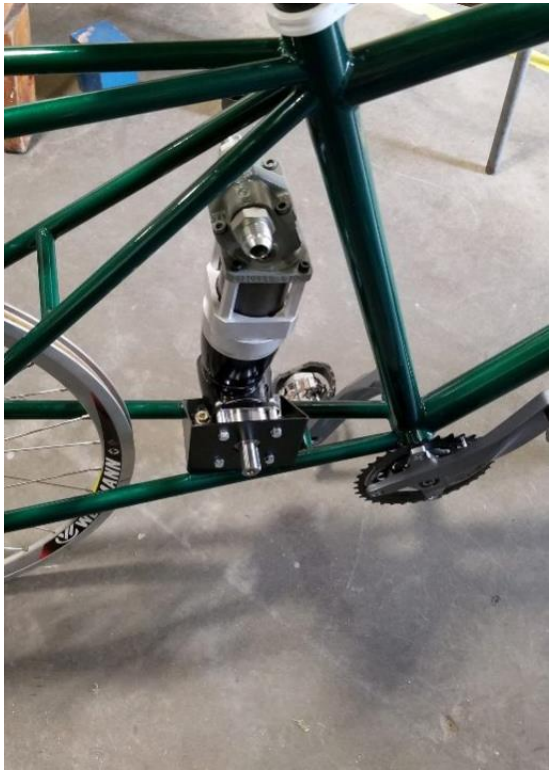




Frame size letter	L
Wheel size	700c
A — Seat tube	50.8
B — Seat tube angle	73.5°
C — Head tube length	18.5
D — Head angle	71.5°
E — Effective top tube	59.0
F — Bottom bracket height	28.5
G — Bottom bracket drop	6.5
H — Chainstay length	43.8
I — Offset	4.5
J — Trail	69.7
K — Wheelbase	107.2
L — Standover	78.1
M — Frame reach	40.9
N — Frame stack	61.1

Drivetrain (Front)

- 2 speed front crankset w/ front derailleur
- 10.3:1 & 6.3:1 gear ratios
- Apex Dynamics right-angle planetary
- Bosch AF2O-5 bent axis pump
- Bent sheet metal and welded mount



Drivetrain (Rear)

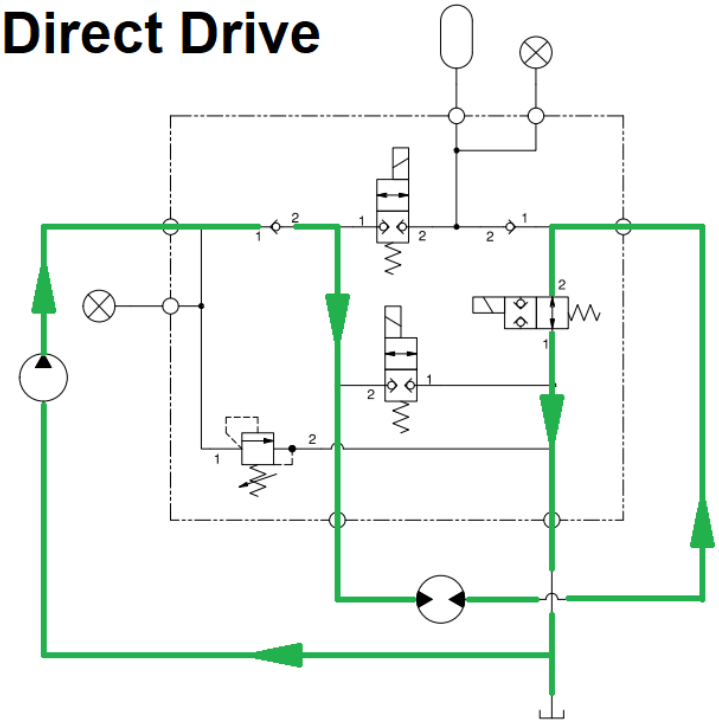
- Steel mount welded to frame
- Chain drive
- 3:1 gear ratio
- Bosch AF2O-5 bent axis pump

Hydraulic Components

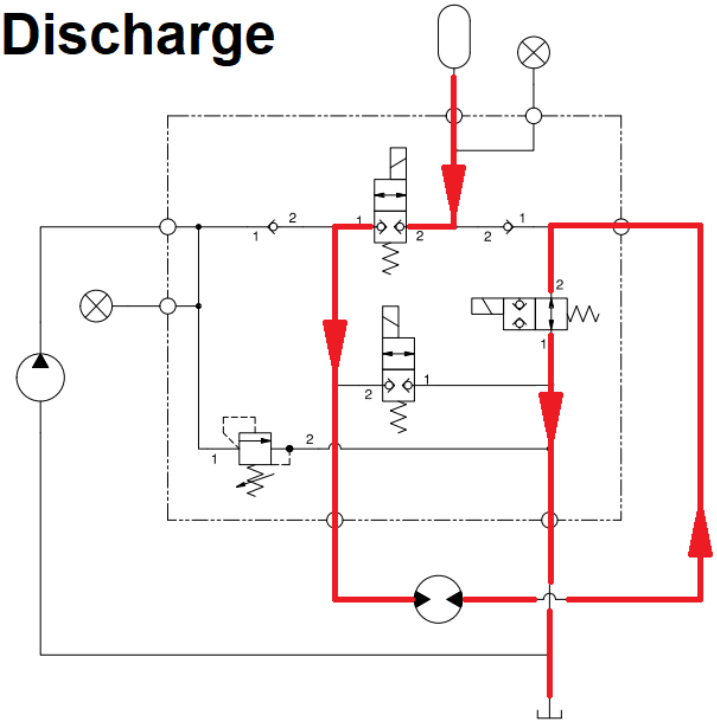
Component	Quantity/Size
Eaton Two-Way/Two Position Poppet Solenoid	3 (1 Nominally Open)
Steelhead Composites 1 Gallon Composite Bladder Accumulator	1
Eaton Direct Acting Relief Valve	1
Eaton Check Valve	2
Manual Proportioning Valve	1
Bosch Rexroth Bent Axis Pump	2
Fittings & Line Size	-6AN
SunSource Custom Manifold	1

Drivemode Circuits

Direct Drive



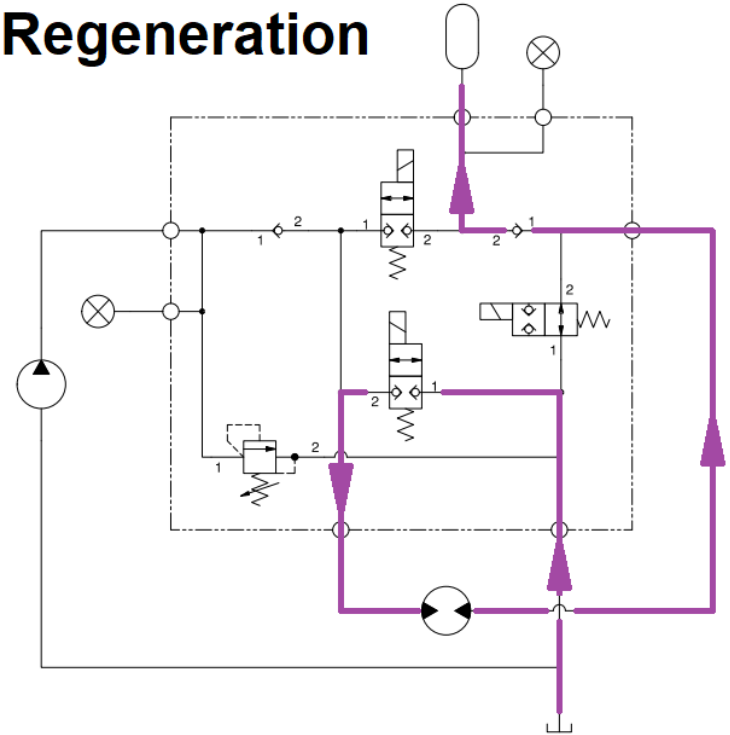
Discharge



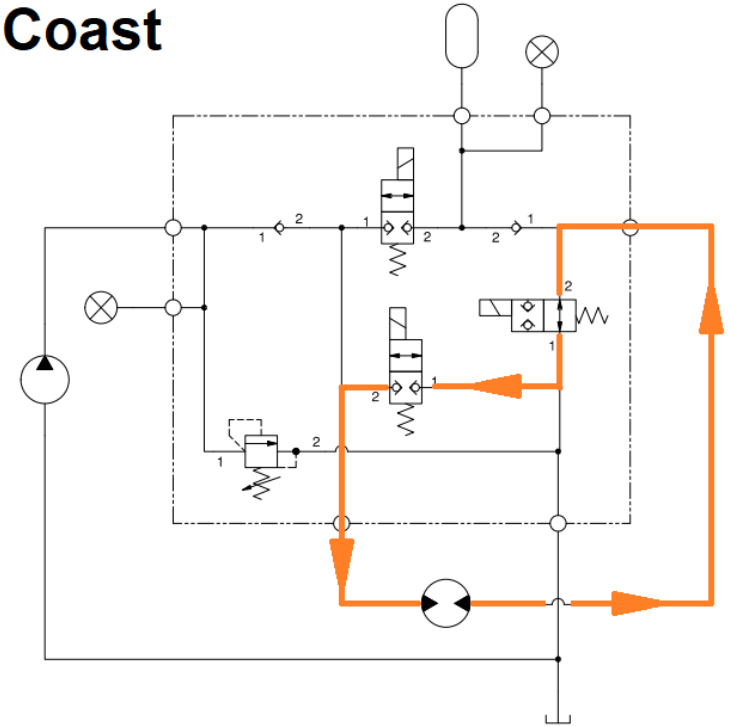
**Dead battery leaves bike in direct drive mode*

Drivemode Circuits

Regeneration



Coast



Hydraulic Analysis

- 4.93 cm^3/rev displacement for pump/motor
- Simscape analysis results
- Direct Drive Mode (17 mph)
  - ~0.9-0.85 gpm for pump/motor flow rate
  - ~690-650 rpm for pump/motor speed
  - ~450-350 psi drop across pump/motor
- Accumulator Discharge (fully open)
  - ~1.5 gpm max for motor flow rate
  - ~1100 rpm max for motor speed
- Circuit Losses @ 31 mph (top speed)
  - Direct Drive ~ 30.2psi (2 solenoids)
  - Regen ~ 23.2psi (1 solenoid, 1 check)
  - Discharge ~ 30.2psi (2 solenoids)
  - Coast ~ 30.2psi (2 solenoids)

Mechatronics

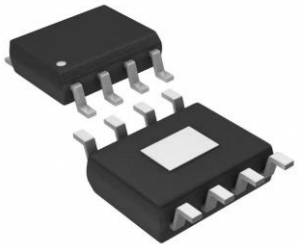
Components

Controller:

Arduino Nano

Solenoid Driver:

Ti DRV 103-H



Display:

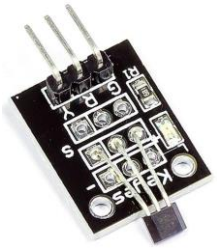
2.8 inch LCD

Pressure Sensor

3000 psi/ 5V

Speed Sensor

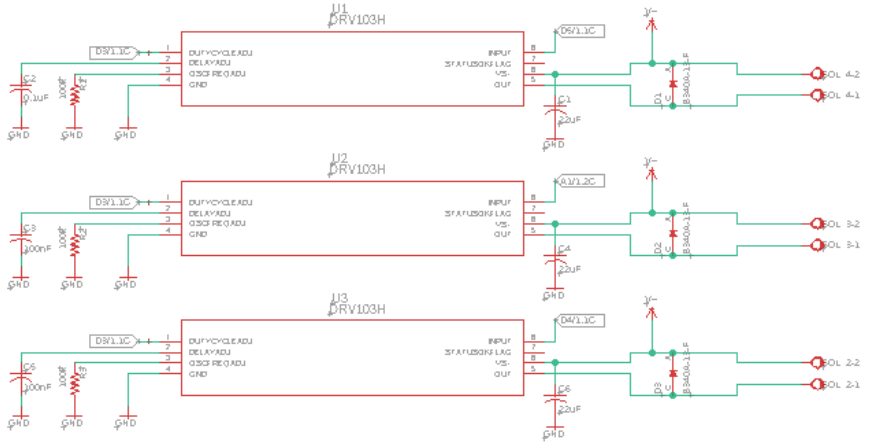
Hall Effect Modules

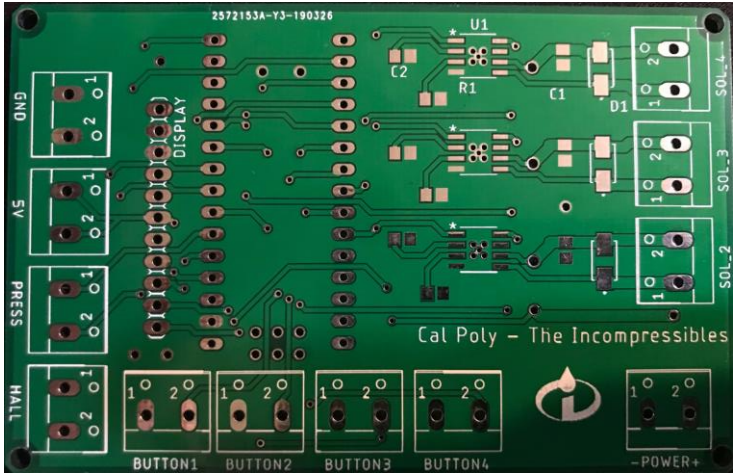


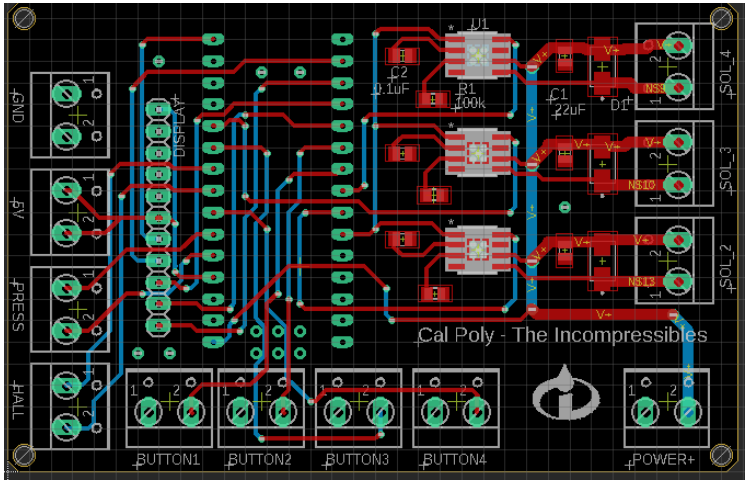
Mechtronics

Custom PCB

- Designed using Eagle
- Arduino Nano MCU
- Peripheral components connected through traces



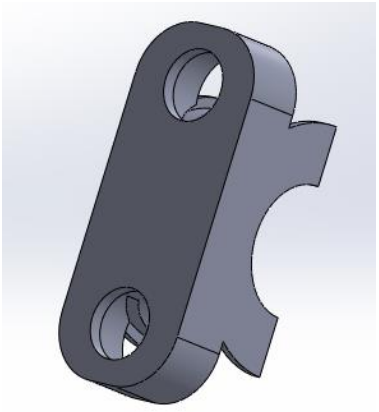




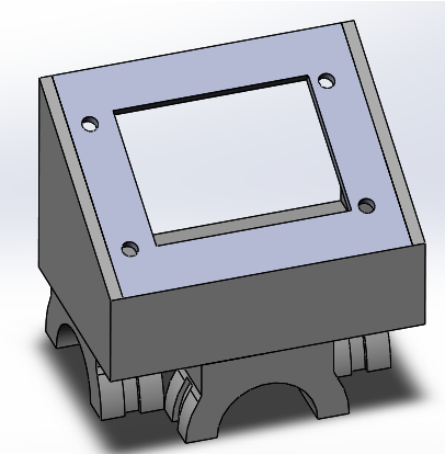
Mechatronics

Mounting

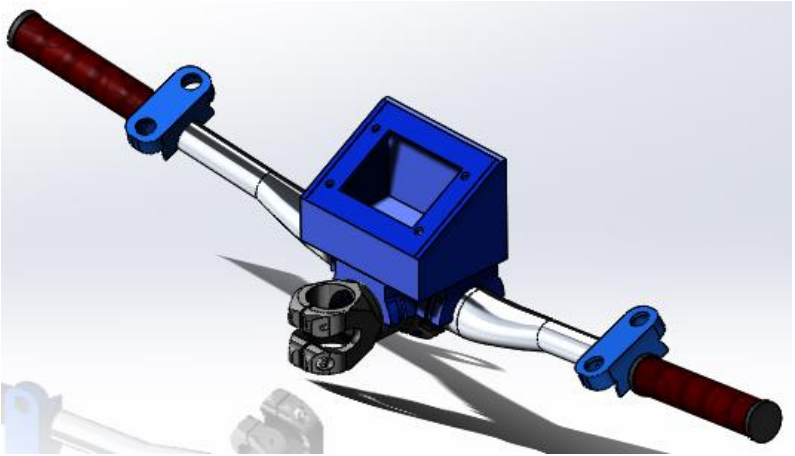
Button Mount



Display Enclosure

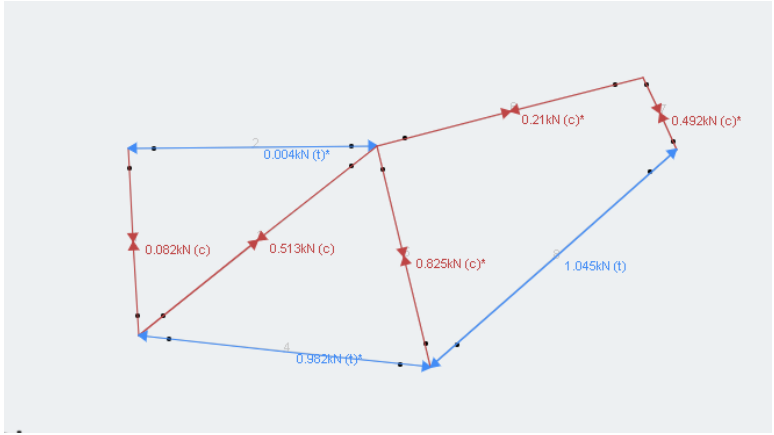


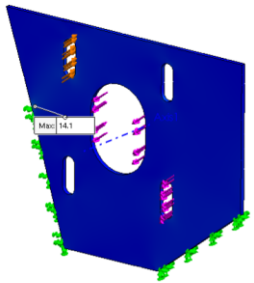
Mounted on Handlebars

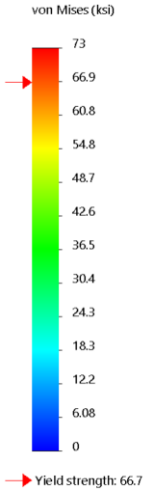


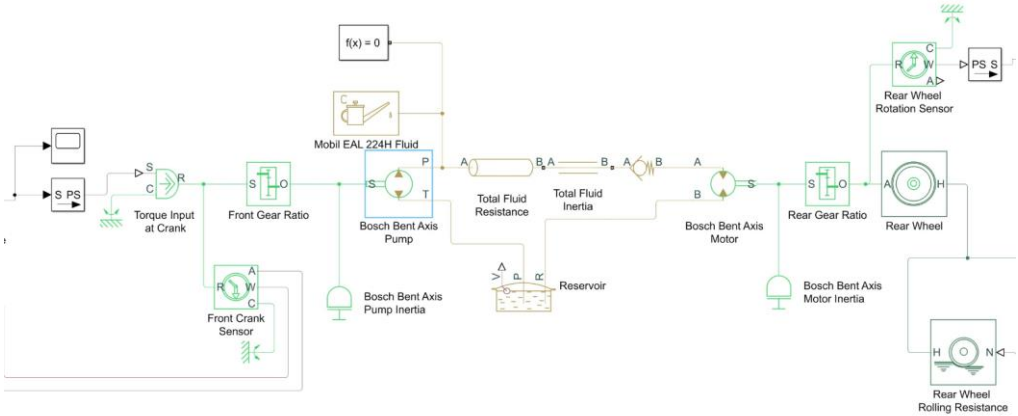
Modeling

- Patterson Control Model
- Truss analysis for frame strength
- FEA on pump/motor mounts
- MATLAB Simscape models for bike performance







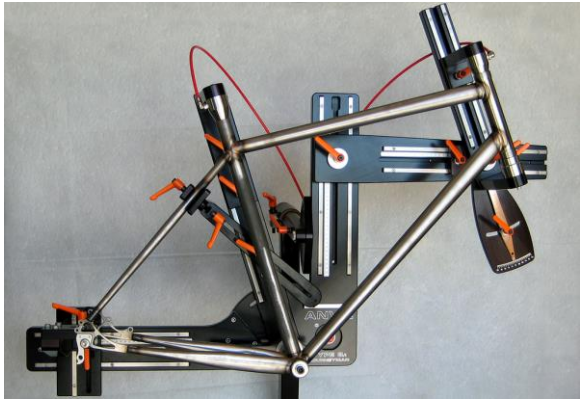


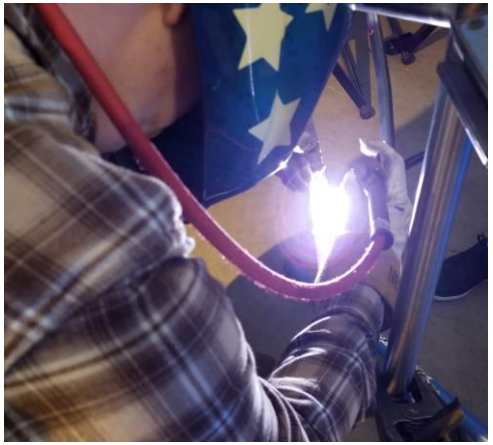
Vehicle Construction

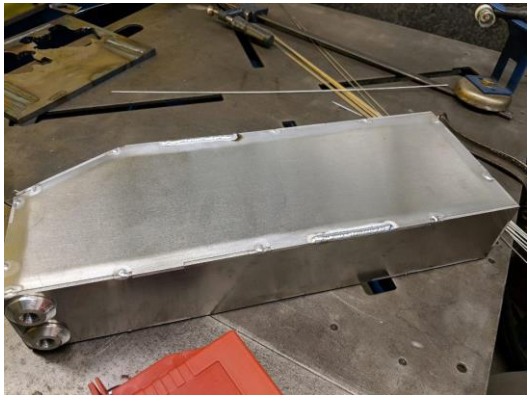
- Mitered frame tubes with Anvil fixtures
- Bent tubes by hand
- Fixtured tubes on final Anvil frame for welding

Vehicle Construction

- Welded frame and mounts together
- Painted then post machined
- BB, crankset, headset installation
- Welded reservoir
- Installed lines and bled system







Vehicle Testing

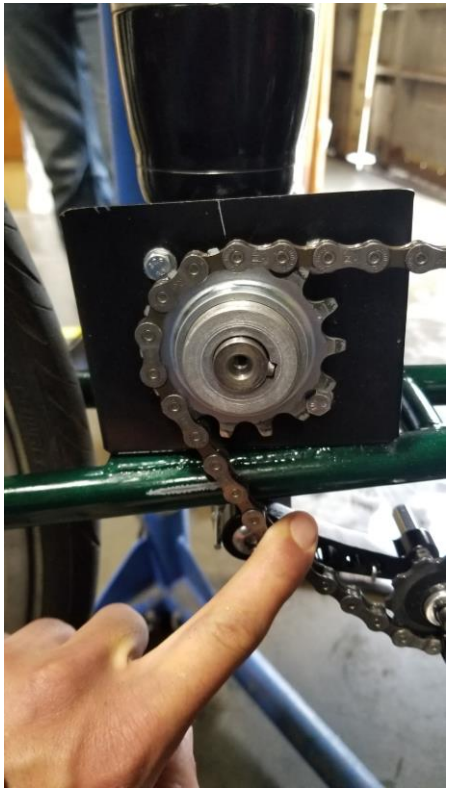
Competition Testing

- Local flat parking lot
- Replicate competition challenges
- Endurance Testing
  - ~4:15 mile time
  - *Goal: <4 min*
- Sprint Testing
  - 21.5 sec - 22.4 sec
  - *Goal: <18 sec*
- Efficiency Testing
  - Score of 52-55 points
  - *Goal: >25 points*
- Accu. Recharge
  - ~3.5 min
  - *Goal: <5 min*

Vehicle Testing

Front Shifting Problem

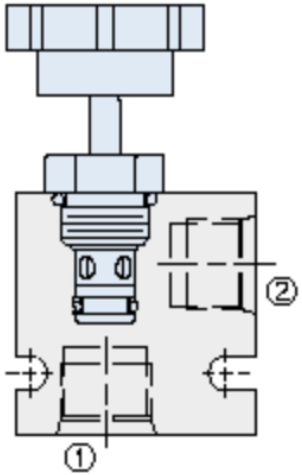
- Chain slipped on smallest front chainring
- Not enough chain wrap on planetary sprocket
- Swapped single jockey for dual jockey wheel tensioner
- Needed more chain tension

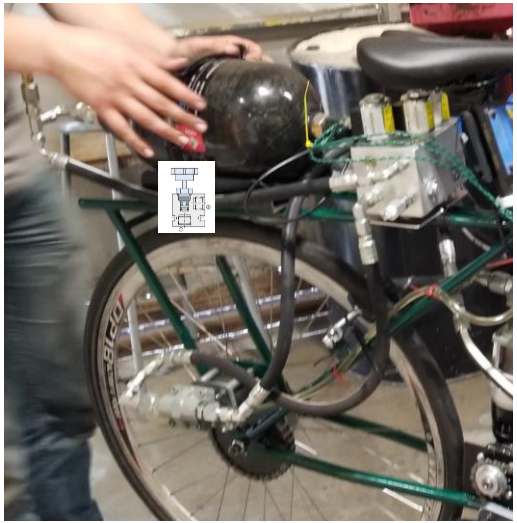


Vehicle Testing

Accu. Discharge Problem

- Pressure spike during accu. discharge blew through seals in motor
- Added proportioning valve to reduce pressure spike





Lessons Learned

- Have a dedicated welder on your team for fabrication
- Redesign placement of front drivetrain for more chain wrap and better chain tensioning
- Investigate pump cavitation while pedaling aggressively and in regen mode
- Factor in large amount of time manufacturing requires
- Check torque on fittings

Thank you!

Any Questions?